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OHIO RIVER POLLUTION SURVEY: BIOLOGICAL STUDIES

Public Health Service
Cincinnati, Ohio

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BIOLOGICAL STUDIES

Supplement "F" to
Final Report to the Ohio River Committee
Ohio River Pollution Survey

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FEDERAL SECURITY AGENCY
U. S. PUBLIC HEALTH SERVICE
STREAM POLLUTION INVESTIGATIONS STATION
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BIOLOGICAL STUDIES

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SUMMARY

The primary purpose of the biological studies in connection with the Ohio River Pollution Survey has been twofold: first, to determine present biological conditions as a record to be compared with conditions after future changes due particularly to remedial measures which may be instituted, and second, to determine the effect, particularly of a destructive nature, of present sources of pollution on stream biological communities and fish life as a guide in judging the need for corrective measures.

Secondary purposes include determination of what biological and chemical conditions may be typical of different pollutional situations, what factors under man's control are involved in creating these situations, and what combinations of these conditions may be allowed for designated stream uses.

This biological supplement is based upon extensive data obtained from the examination of plankton and fish collections and correlated with chemical and bacteriological findings. Fish collections were made only during the second year of study and did not include the middle third of the basin nor the main Ohio River.

Biological life is closely related to problems of stream sanitation. A change in the magnitude or the nature of the pollution load will almost without exception cause a change in the lower biological forms and, as these are food for fish life, fish, in turn, are also affected. An increase in the minute forms or plankton may affect water supply due to taste and odor troubles or filter clogging difficulties caused by certain types when present in large numbers.

While pollution is usually considered to damage or destroy aquatic life and recreational values and this is frequently the case, it is possible for moderate pollution to provide food material and increase aquatic life, particularly in an otherwise naturally barren stream. This might be termed a beneficial effect as far as fish life is concerned and may parallel a detrimental effect if the increase in plankton causes taste, odor and filter clogging difficulties in water supply systems.

Corrective measures in the nature of sewage treatment remove a portion of the organic pollution load and stabilize a further portion. Thus the destructive effect of pollution on aquatic life may be corrected and, at the same time, a large measure of the food material retained. An over-all benefit to aquatic life may thus be accomplished by a treated effluent. Pollution has only a damaging effect on water supply, and treatment measures reduce this effect to a greater or lesser degree but never entirely eliminate all effects.

Pollutants which enter streams from city sewers or organic industrial plants, such as canneries, meat packing houses and creameries, affect the aquatic life in a variety of ways. The waste may have an immediate toxic effect on aquatic life or, more usually, the waste may induce rapid multiplication of aerobic bacteria which sharply lower the dissolved oxygen concentration, sometimes to the asphyxial level for fishes, or even to total depletion.

The lowering of the dissolved oxygen concentration to a point below 3 p.p.m., accompanied by a high oxygen demand and high coliform bacterial population, is evident in a zone of heavy organic pollution, below sources of pollution, the distance depending upon the temperature, rate of flow and physical character of the stream. Biologically, this region is dominated by bacteria-eating protozoa, colorless flagellates and chlorophyll-bearing flagellates that require a rich cultural medium. The fish are principally of the coarser varieties, such as carp and buffalo.

This zone gradually blends through an intermediate stage into a fertile zone which is characterized by a large variety and volume of photosynthetic plankton organisms and dissolved oxygen above 5 p.p.m. In this region is usually found a large mixed plankton population, reflecting the maximum fertilizing effect of the upstream pollution. Fish are varied and abundant, there being large numbers of market and food fishes.

Further downstream the plankton volume is diminished. This reduction in fish food has a direct effect upon the fish population, so that the game fishes are the dominant forms.

Industrial wastes such as effluents of coal mines, steel mills, paper and pulp mills, oil and gas refineries, in sufficient concentration, reduce the aquatic life, either by a direct toxic action or by a reduction in hydrogen ion concentration (pH 4.5 or less). The flesh of fish in streams polluted by oil refineries or paper mills is tainted and cannot be used as food.

The condition of a stream from a biological standpoint will vary with conditions. During spring high water, for example, zones of heavy pollution and intermediate zones are scarce. As the year advances and low-flow conditions set in, the polluted areas are more distinct and it is the summer low water period that is critical to the fish population of a stream. A period which exterminates a fish population may be only one day of the year and it is not offset by the tolerable conditions of the other 364 days.

In general, localities where normal biological communities and fish life were found to be detrimentally affected or destroyed and pollutional forms found to predominate, corresponded to localities where information on sources of pollution and chemical and bacteriological data indicated that large sources of pollution exist. Outstanding examples are the upper Ohio River and tributary areas, where acid pollution, chiefly from mines, has destroyed all but the very specialized aquatic forms capable of existing in acid water, and below the larger cities and in some instances larger industries that continue to discharge wastes without treatment. Conditions below individual sources of pollution and in other areas throughout the basin are discussed in the drainage basin summaries.

INTRODUCTORY AND GENERAL

Authorization

This biological survey was conducted as part of the Ohio River Pollution Survey, authorized in Section 5 of the River and Harbor Act passed August 26, 1937. This section reads in part as follows: "The Secretary of War is hereby authorized and directed to cause a survey to be made of the Ohio River and its tributaries to ascertain what pollutive substances are being deposited directly or indirectly therein, and the sources and extent of such deposits, and with a view to determining the most feasible method of correcting and eliminating the pollution of these streams."

Activities in connection with the Ohio River survey have divided themselves into three broad groups: (1) The collection of data on water supply, sewerage, sewage disposal and industrial wastes,together with the location, character and amounts of polluting wastes; (2) Laboratory studies (biological, chemical and bacteriological) relative to the sanitary conditions of the streams at the time of sampling; (3) Hydrometric studies on the stream discharge, time of flow, and the possible dilution at the time of sampling.

When the survey was originally planned, the watershed was to be divided into three parts and a year was to be spent on each third. The middle third, from Point Pleasant, West Virginia, including the Big Kanawha Basin, to Carrollton, Kentucky, including the Kentucky River Basin, was studied in 1939. However, due to subsequent shortening of the time allowed for the survey, both the upper and lower thirds of the watershed were studied in 1940.

In order that this supplement may be complete in itself, certain data on stream flow, drainage basin characteristics, population, bacteriological data and chemical data,presented in the main body of the Ohio River Pollution Survey report, have been repeated.

The Scioto River has been studied as a separate project (U. S. Public Health Bulletin No. 276) and is discussed briefly in Appendix I to this supplement. The Tennessee River is being studied by the Tennessee Valley Authority, and that organization has submitted a brief progress report on the studies, which is presented as Appendix II to this supplement.

Personnel and Acknowledgments

The laboratory operations of the survey were performed under the administrative direction of Senior Sanitary Engineer J. K. Hoskins, in charge of the Stream Pollution Investigations Station at Cincinnati, who was succeeded in July, 1940, by Medical Director H. E. Hasseltine. The work was organized and carried out under the technical direction of Senior Sanitary Engineer H. W. Streeter, with Associate Biologist F. J. Brinley in immediate charge of the biological studies. Junior Aquatic Biologist L. I. Katzin assisted Dr. Brinley during the second year of the work.

Special Expert W. C. Purdy and Senior Biologist J.B.Lackey, from the regular staff of the Cincinnati station, co-operated in acting as technical advisers in various phases of the work. Dr. Lackey also prepared Appendix I to this supplement, covering biological studies on the Scioto River, based on his studies covered in Public Health Bulletin No. 276.

Numerous fish specimens were submitted to the Laboratory of Interior Fisheries Investigations, U. S. Bureau of Fisheries, under the direction of Dr. M. M. Ellis.

Grateful acknowledgment is made to Dr. E.L.Bishop,Director of Health of the Tennessee Valley Authority, for the "Discussion of the Biology and Pollution of the Tennessee River," which is included as Appendix II of this supplement. The appendix is a joint report of the Forestry Relations and the Health and Safety Departments and was prepared by Dr. A. H. Wiebe, Chief, and Dr. C. M. Tarzwell, Associate Aquatic Biologist, Biological Readjustment Division, Forestry Relations Department, and Mr. G. R. Scott, Senior Sanitary Engineer, and Dr. A. D. Hess, Assistant Aquatic Biologist, Health and Safety Department.

Physical Characteristics of the Ohio Basin

The Ohio River, which is formed by the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, drains an area of 204,000 square miles in the eastern central United States (Figure 1), including parts of the following fourteen states: New York, Pennsylvania, Maryland, Virginia, North Carolina, Ohio, Indiana, Illinois, West Virginia, Kentucky, Tennessee, Georgia, Alabama and Mississippi. The tributaries studied in the biological survey consisted of the Allegheny, Monongahela, Muskingum, Hocking, Little Kanawha, Kanawha, Big Sandy, Little Sandy, Guyandot, Miami, Little Miami, Licking, Kentucky, Green, Wabash and Cumberland Rivers.

Limestone and shale are the common bedrocks found in the Ohio Basin. The northern section of the watershed is overlaid with glacial drift, forming the deep and fertile soils in the western section of the basin. In the Appalachian highlands, in the eastern part of the basin, the soil is light and sandy, while in the south central basin it is alluvial, consisting of a mixture of rich loam and clay. The important natural deposits are coal, iron, oil and gas. Portions of the Appalachian coal fields extend along the eastern section of the basin from western New York southwest to Alabama. The so-called eastern interior fields lie in parts of southwest Indiana, Illinois and western Kentucky. Oil and gas have been developed in the Appalachian fields of New York, Pennsylvania, Ohio, West Virginia and Kentucky, the Lima-Indiana fields in southwest Ohio and eastern and southern Indiena, and in the Illinois fields in central and southern parts of the state.

Three major physical divisions characterize the Ohio Basin. Rough hills and mountains of the Appalachian highlands prevail in the east. Low hills, of the interior plateaus, occupy the southwest. Gently sloping, glacial lowlands of the interior plains are found in the north and northwest.

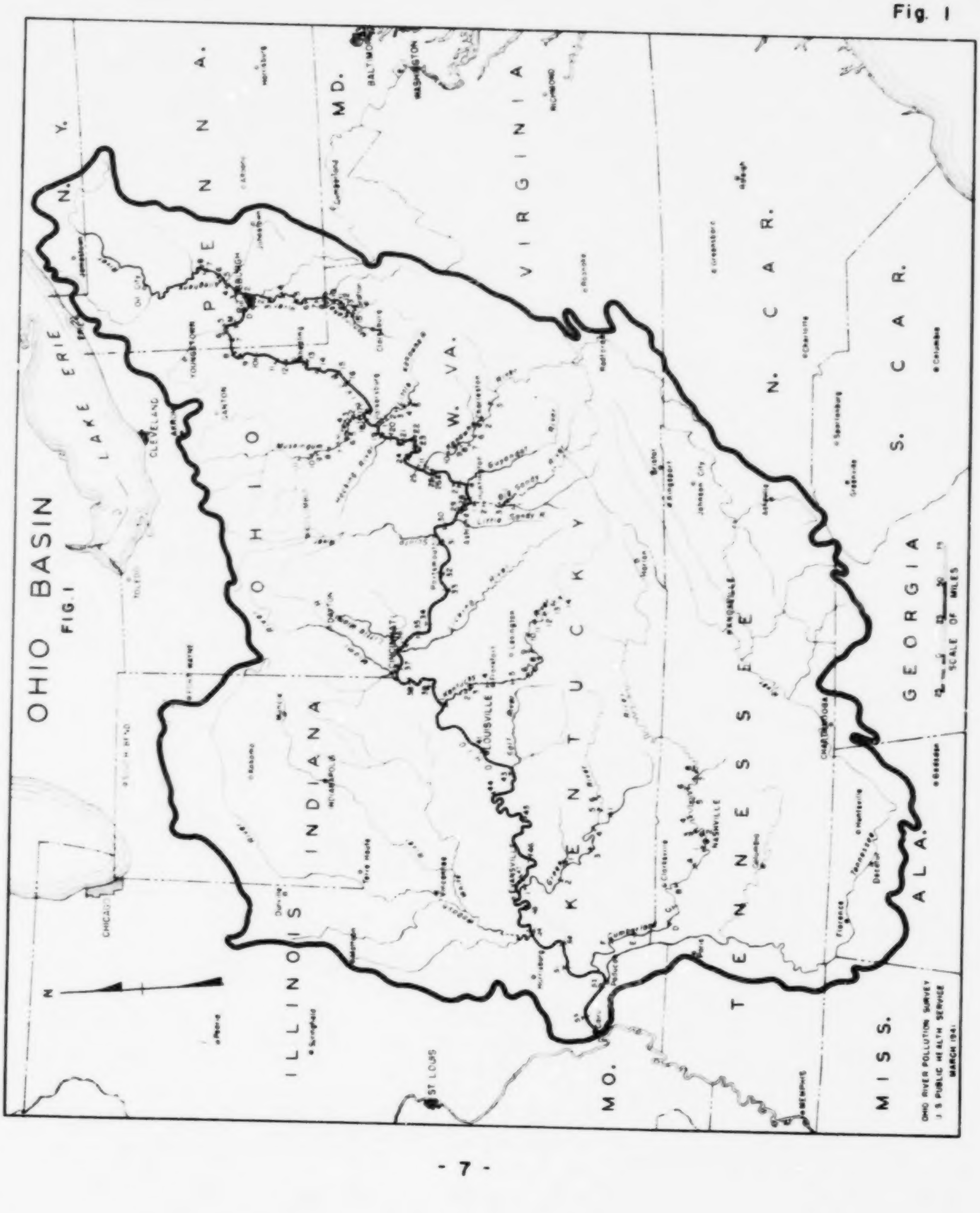
Navigation on the entire length of the Ohio River, during all times of the year, has been made possible by the construction of fifty-three locks and dams providing a nine-foot low water channel. Locks and dams also have been built on the Allegheny, Monongahela, Muskingum, Kanawha, Kentucky, Green and Cumberland Rivers.

Introduction

There are two principal factors which influence all biological survival: (1) Self-preservation, which includes securing and assimilation of food, and escaping enemies, and (2) Race preservation, which includes reproduction in addition to the functions of self-preservation.

Food, therefore, becomes a very important and often the limiting factor in the life of an individual, race, or of a biological community. One aspect of the food relation of a community is expressed as the "food chain" or chemical cycle of the ecologist. Plants synthesize complex organic compounds

Fig. 1


OHIO BASIN
FIG. I
LAKE ERIE
N.Y.
PENNA.
MD.
VIRGINIA
W. VA.
OHIO
INDIANA
ILLINOIS
KENTUCKY
TENNESSEE
N. CAR.
S. CAR.
GEORGIA
ALA.
MISS.
MO.
N
CLEVELAND
YOUNGSTOWN
CANTON
PITTSBURGH
BALTIMORE
WASHINGTON
RICHMOND
TOLEDO
CHICAGO
ST LOUIS
MEMPHIS
DAYTON
CINCINNATI
LOUISVILLE
INDIANAPOLIS
NASHVILLE
CHATTANOOGA
KNOXVILLE
SCALE OF MILES
OHIO RIVER POLLUTION SURVEY
U S PUBLIC HEALTH SERVICE
MARCH 1941

from soluble salts and carbon dioxide, either by means of solar energy through the agency of a pigment such as chlorophyll, or by means of other energy-yielding chemical reactions. These plants and their products may form food for various animals who, in turn, may be eaten by larger animals. Eventually, carbon dioxide is returned to the air, and soluble materials to the soil and water through the agency of the natural chemical processes carried on by the higher organisms, or through the destructive action of bacteria, molds and fungi upon organic material no longer living. Thus, the cycle is completed.

The other important aspect of the community food relation lies in competition for the same (usually) limited food supply between organisms not in the relation of prey and predator. In the process of organic evolution the competition for survival has led to such diversifications that there is usually a single species, or restricted group of species, best fitted to survive and reproduce under a given set of environmental conditions. Conversely, it is usual that a certain set of conditions must obtain before a given species can hold its own in competition with others.

The above considerations hold for the aquatic environment as well as for the terrestrial and aerial. The microscopic aquatic plants and plant-like animals synthesize organic materials from the chemical constituents of their fluid surroundings, under the influence of sunlight, giving off oxygen as a by-product. These minute organisms may form the food of larger Protozoa, of Mollusca, Rotifera, small Crustacea, and larval or even adult fishes. Such plankton-feeders may in turn form the food of larger fishes, and so on. Eventually, compounds of carbon no longer living (wastes, dead organisms) are returned to the water, and broken down through progressive steps, by the bacteria, until nothing but soluble inorganic salts are left. and the cycle commences again. The amount and kind of aquatic life depends ultimately upon the concentration and availability of food in the stream. Thus, a stream may be considered as a nutritive medium for the life growing therein.

Many factors may temporarily interrupt or modify the chain of events, as by removing certain links such as the fish, or by adding organic material in bulk. The most significant factors are man's activities. For the moment attention will be focused on the material he places in the water, hereafter termed "pollutants."

For practical reasons, it is necessary to limit the discussion of this matter to the two ends of the food chain - the microscopic forms that turn material in solution into their own organic substance, and the fishes. The intermediate forms are all important, but are eventually dependent upon these lowest forms. The fish, in turn, are the members of the aquatic community that come most directly to the attention of man, and are most usually his immediate concern.

A small stream which has just received a heavy load of domestic sewage can be taken as an example. This sewage is compounded of human excrement, waste food, paper, etc. It is immediately attacked by the bacteria of the stream. Such a point of gross pollution is characterized by large numbers of coliform bacteria (from excrement), a high rate of oxygen consumption, due to organic material being oxidized, a low dissolved oxygen value due to the use of the oxygen by the rapidly multiplying bacteria, and usually a low population of phytoplankton (plant plankton forms). This deficiency of plankton may be due to general toxicity of the sewage, particularly if industrial wastes are involved, and of the initial by-products of bacterial decomposition, and to the lack of available food materials in solution.

Several species of bacteria-eating Protozoa, such as *Paramecium*, *Stentor*, *Colpoda*, *Glaucoma*, *Colpidium*, *Vorticella* and *Carchesium*, may occur in significant numbers in grossly polluted areas, more abundantly in the slime and scum on stones and sticks and on the surface of the bottom mud than in the plankton. Fish, with the possible exceptions of buffalo and carp, are absent under these conditions. As the sewage moves downstream, the complex organic compounds are reduced by bacterial and chemical means to simpler chemical compounds. Certain microscopic plants, such as *Euglena*, *Lepocinclis* and *Phacus*, which thrive in a medium rich in organic material, may make their appearance in large numbers. As chemical breakdown continues, these plants will give way to *Pandorina*, *Eudorina*, *Trachelomonas*, *Scenedesmus*, *Chlamydomonas* and *Mallomonas*. Certain Protozoa, such as *Domatomonas*, *Codonella*, *Strobilidium*, *Strombidium* and *Cyclidium*, may appear, but never abundantly. Further downstream, various species of *Chrysococcus*, *Cryptomonas*, *Chroomonas* and *Dinobryon* are found in large numbers where the water is approaching purity. Plankton is scarce except for diatoms and these last named forms in streams that receive no organic pollution of any sort.

It is apparent that domestic sewage acts as a fertilizer for aquatic plants in the same manner as organic matter does for land plants. The carbohydrates and proteins in fresh sewage are not equally available for all plant growth and meet the nutritional requirements of different organisms in succession during the series of changes leading to inorganic end products. The order of development of the various species of planktonts depends upon their reaction to the concentration of these various products. Chrysococcus and Cryptomonas are found in the cleaner portions of watercourses low in organic matter. Many species of Euglena prefer polluted streams (rich medium) where purification of the sewage has not approached completion. Pandorina and Trachelomonas may be considered as intermediate forms, preferring culture media of lower organic concentration. So, in the natural course of events, the highest population of plankton occurs at some distance below the source of pollution, where the concentration of soluble materials is suitable for the largest number of species.

Fish life increases in regions where the heaviest plankton populations occur. The plankton furnishes food directly for many larval and some adult fishes and also for water fleas, rotifers, etc., which are important foods for larger fish. The phytoplankton, through the process of photosynthesis, produces oxygen which may be of considerable importance in maintaining a high dissolved oxygen concentration. The coarse fishes are found nearest the source of pollution and game fish appear further downstream.

Beside the presence or absence of sewage, the plankton population is influenced by temperature, hydrogen-ion concentration, turbidity, variations in stream flow, and seasonal changes. Plankton develops more rapidly at higher water temperatures, while sudden temperature drops reduce the plankton population. At temperatures of 10° C. or lower, a large proportion of the plankton organisms disappear. Certain species will withstand lower temperatures than others. Chrysococcus can be collected when the stream is frozen over. Variations in the hydrogen-ion concentration between pH 6 and 8.5 seem to have little, if any, effect on plankton. Higher acidities (pH 4 or less), resulting from acid pollution, may destroy all plankton except a few resistant species.(1)

A sudden rise following rain will often flush out plankton, and several days may elapse before the organisms again appear in numbers. High turbidity following rain is also detrimental to plankton. A slow-moving stream which gives more time for bacterial action is more suitable for the development of plankton organisms than a rapid stream. Pool conditions during low flow may result in the development of a large number of certain species not normally present in such numbers. These may be distributed several miles downstream by increased flow following rains. Conversely, a rain may wash the plankton out of a swamp or oxbow lake into the main stream, thereby causing a sudden increase in the amount of plankton. The constant flow of a stream will carry plankton a distance downstream, and a peak in the plankton population may slowly travel the entire length of the stream.

In the discussion to follow, the effects of pollution introduced directly or indirectly by man will be considered from the standpoint of the changes in food supply and the various "ecological niches" along the watercourse. Only the protozoan and normal algal constituents of the plankton will be considered, together with the fish.

Method and Procedure

The majority of the plankton samples were taken with those for the chemical and bacterial studies, by collecting 250 ml. of water a short distance below the surface. Samples were taken once each week at certain key points along the Ohio River and its tributaries, while at other points samples were taken only once, or at irregular intervals. Samples were brought to the Cincinnati laboratory either fresh or preserved in 4 per cent formalin. One hundred cubic centimeters of the water was centrifuged for five minutes at a speed of about 2,500 r.p.m. The supernatant liquid was decanted, leaving the organisms originally present concentrated in about one cubic centimeter of fluid, the exact amount being determined by a pipette, delivering 25 drops per cubic centimeter. The number of organisms in one-fourth of the "catch" was determined by counting under the low and high powers of a compound microscope. The number of organisms was computed per cubic centimeter of the original sample. For a detailed report of the method, see Lackey.(2)

The results of the plankton determinations are given in the tables in numbers per milliliter for the various taxonomic groups. The plankton volume is expressed in thousands of parts per million (M.p.p.m.). Volumes were determined by multiplying the number of individuals of the various species by the volume of an average individual of the species. These average volumes were obtained from figures of Lackey and Kehr (unpublished). The volume curves in the graphs are subdivided to show the proportion of Class I, Class II and Intermediate organisms. Class I organisms are those which tend to favor water of good sanitary quality and are able to survive scarcity of organic food, sudden changes of and low temperatures, and relatively high acidity.

In this class are included such genera as Chrysococcus, Cryptomonas, Dinobryon, Chromulina, and the various genera of diatoms (Bacillarieae) encountered. Class II is made up of those forms which favor a rich nutritive medium or feed upon bacteria and solid particles. In this group are included Euglena, Lepocinclis, Phacus, Synura, Anabaena, and the bacteria-eating ciliates such as Paramecium, Colpidium, Vorticella, etc. All planktonts not definitely falling into the above extreme groups are lumped together as Intermediates.

It is clearly realized that these genera are not homogenous but that certain species differ in their food requirements and tolerance to environmental conditions. Owing, in many cases, to the inability to determine species in formalin-preserved samples, it was considered more advantageous to keep the above grouping and to note particular cases where inconsistencies may be due to species differences. The principal example is Euglena mutabilis, found in abundance in acid streams which are free of organic pollution, which would indicate that it belonged to Class I Likewise, Stephanodiscus, found in the Wabash Basin, has a distribution which would indicate that it belonged to Class II. In these studies, however, these exceptions were not separated from their taxonomic groups, Euglena and the Bacillarieae, respectively.

Fish collections were made where possible in the upper and lower thirds of the watershed by means of seines and a trap net (fyke net). No fish collections were made during the season of 1939 in the middle third of the basin. Whenever fish collections were made, plankton and chemical samples were taken. Information on fish life was obtained whenever possible from local fishermen and residents. Results of the biological studies have been compared and correlated in this report with the chemical and bacteriological findings.

In the following discussion, certain terms will recur repeatedly. Pollutants shall be defined as any material introduced into the stream from without, usually of an organic nature. The symbol "D.O." refers to dissolved oxygen, measured in parts per million by the Rideal-Stewart and azide modifications of the Winkler method. The term "B.O.D." (biochemical oxygen demand) refers to the amount of oxygen disappearing from a sealed sample of water at 20° C. in the course of five days (due to microorganismal action), and is usually expressed in parts per million. Alkalinity is a measure of the carbonate and bicarbonate buffering capacity of the water, determined by titration with dilute sulfuric acid using methyl orange indicator. Acid activity is expressed in the usual pH units. In this report, wherever acidity is used, it refers to acid activity as expressed by the term "pH." Turbidity was determined by the Jackson turbidimeter and is given as parts per million. "Coliform organisms" refers to bacteria of the coli-aerogenes group, given in most probable numbers per milliliter. These determinations follow the procedure given in Standard Methods of Water Analysis (American Public Health Association, 8th Edition, 1936). The azide modification of the Winkler D.O. determination is that of Ruchhoft, Moore, Placak.(3)

The figures following the word "mile" refer to the mileage from the junction of the tributary in question with the Ohio River, except the White River, where the mileage given is taken from its junction with the Wabash River. The mileage on the Ohio River is taken from the confluence of the Allegheny and Monongahela Rivers at Pittsburgh. On curves showing volume of plankton in thousands of parts per million (M.p.p.m.) the upper line represents the total volume, the space between the upper and middle line represents the volume of intermediate organisms, the space between the middle and lower line represents the volume of Class II organisms, and the lower line represents Class I organisms.

DRAINAGE BASIN SUMMARIES

The biological data collected during the Ohio River Pollution Survey are discussed briefly in summaries covering the individual tributary drainage basins and the main Ohio River. The tributary summaries have been grouped in the middle, upper and lower thirds of the Ohio River Basin and are discussed in that order. The middle third tributaries are discussed first, as the first year of study was spent in this area and many more samples were examined than was possible in the case of the upper and lower thirds. The Scioto River in the middle third is discussed in Appendix I, and the Tennessee River in the lower third is discussed in Appendix II. The Beaver River in the upper third was not covered, due to time limitations.

Middle Third

Miami River

The Miami River rises in the west-central part of Ohio in Logan County, near the village of Bell Center (elevation 980 feet). The stream starts as a small brook, meandering through a wide valley, and flows the short distance to Indian Lake, the largest body of water within the state. From Indian Lake, the stream continues in a westerly direction to Dayton (90 miles), where it is joined by the Mad and Stillwater Rivers. At Dayton the direction of flow shifts toward the southwest corner of Ohio. The Miami is joined by the Whitewater River of Indiana at a point 4.8 miles from its mouth and thence flows into the Ohio River near Cleves, at the Ohio-Indiana state line.

The Miami Basin comprises a total area of 5,385 square miles, of which 1,590 square miles are in the Whitewater Basin mostly in Indiana. Flood control dams have been constructed at Englewood on the Stillwater, at Phoneton on the Miami above Dayton, and on the Mad River above Dayton.

The northern part of the basin is level to gently rolling; the soils are rich, and agriculture is prosperous. The southern part is more eroded, the slopes are steeper and soils less fertile than in the northern part. The rocks which underlie the basin are limestone and shale. The average slope below Middletown (mile 53.6) is about 3.6 feet per mile, and the maximum and minimum discharges at the mouth of the river are 478,000 and 340 (summer minimum at Hamilton) cubic feet per second, respectively.

The population of the Miami Basin was about 830,000 in 1940. Over sixty per cent of the population was urban and ten per cent more lived in incorporated towns of less than 2,500. The population density was about 155 per square mile, considerably above the average for the entire Ohio Basin. The population density of the Indiana portion of the basin was about 75 and the Ohio portion about 183 per square mile.

The principal cities in the Miami Basin are Dayton, Springfield, Hamilton, Middletown and Piqua, Ohio, and Richmond and Connersville, Indiana. The total population of these towns is 427,286 (1940), which is more than half the population of the basin. All of these cities are industrial and manufacturing centers. The principal products are paper, machinery and tools, sheet metal and textiles.

In order to study the seasonal distribution and variation of plankton, a series of samples was taken at Cleves at weekly to biweekly intervals, from May 16 to December 12, 1939. The results are shown in Figure 2 and Table 1. The first sample was taken on May 16 when the turbidity was low (about 10 p.p.m.). The plankton volume was high, largely due to diatoms. The high D.O. value of about 10 p.p.m. is, in all probability, due to the large plankton population. During the six-week period between this date and June 26, more than three inches of rain fell. Owing to the high turbidity, plankton samples were not taken. On June 26 the water had cleared sufficiently to continue plankton examinations. The total plankton volume was low, due, no doubt, to previous high turbidity and the flushing out of the stream by the frequent rains. This was reflected in the low coliform organism count and low B.O.D.

On July 11 the turbidity was again high, due to previous rains, and the plankton was washed out of the river. July 17 showed a slight recovery of plankton, accompanied by a drop in turbidity. The plankton population again started to rise on August 2, reaching the highest value of the summer - about 10 M.p.p.m. - on August 28. Rain on September 4 may have influenced the drop in the plankton population.

The plankton rose slowly to about 4 M.p.p.m. in the next several weeks, until the advent of cold weather. The temperature dropped to 12° C. on October 17 and continued falling to 7° C. on December 12. This resulted in great depression of the plankton population other than diatoms. During this period the river was in a stable condition as light rains fell only occasionally.

A series of samples was collected at various stations from Cleves to Miamisburg at intervals from June 27 to October 26. The results are plotted in Figures 3 and 4. The figures indicate that there is a strong tendency for the dissolved oxygen and the B.O.D. to vary inversely, and for the B.O.D. and the number of coliform organisms to vary in the same direction. Exceptions occur after the middle of August, a majority of which may be fairly readily explained.

Thus, the unexpectedly high dissolved oxygen values found along the river on August 17 seem to be attributable to the high plankton volumes of that date. This relation of the plankton to dissolved oxygen is also indicated at stations above Middletown and near Troy and Piqua on the upper river on September 14. The erratic values for August 31 cannot be readily explained. It should be pointed out, however, that after July the river was in low-flow "pool" condition, the characteristics of a stream at low water being quite different than during high water.

A further element complicating the coliform organism - B.O.D. - D.O. relationship at this season is the introduction of organic industrial wastes, which have high B.O.D. values in the stream, are not accompanied by coliform organisms, and have a variable availability as food for the plankton. Cannery wastes may be mentioned as typical of this class of pollutants. Such material may account for the high B.O.D. observed below Hamilton on September 29, as well as other discrepancies noted in the curves. Certain other irregularities, such as the dissolved oxygen peak at Franklin on September 29, are not at present to be explained. The unpredictably high dissolved oxygen value at Cleves on October 26 is presumably related to the lower water temperature and greater oxygen solubility at the lower temperature. Other oxygen differences, such as the absence of a sharp oxygen peak at Sidney, September 24, to correspond with the plankton peak, may be due to the difference in composition of the plankton compared with the plankton further downstream (diatoms instead of flagellates of various kinds).

There are certain fairly definite seasonal and weather influences affecting the plankton. Summer warmth, sunshine and low water tend to increase the plankton population, aided by the low turbidity of this season. Rains tend to wash out the stream and deplete the plankton (the curve of August 3 shows the condition following heavy rain), and low or rapidly dropping temperatures take heavy toll of the less-resistant planktont. In addition to these general factors, a stream such as the Miami shows characteristic effects of the various sources of pollution along its course.

Hamilton, with a sewered population of 54,600, no sewage treatment plant, and many industries - coke plant, textile mill, meat packing house, paper mills and several creameries - tends to raise the volume of the river plankton, with the peak occurring further downstream, as at Venice, and Class II organisms form a large portion of the plankton.

Middletown, with a sewered population of 35,000 and no sewage treatment plant, has a number of paper mills, and it is probably the effect of this heavy load of industrial waste that causes a sharp local depression of the plankton volume. During summer conditions this depressive action may not be well marked. The peak of the Middletown fertilization effect probably comes somewhere in the vicinity of Hamilton.

Franklin is a smaller town, having a sewered population of 4,000, and several paper mills. The town has a secondary sewage disposal plant under construction (1939). In general, there is a rise in the plankton population immediately below Franklin. The only exceptions to this occur in the series of July 20 and September 29. The factors involved here are not known.

Miamisburg has a sewered population of 5,300, two paper mills, and a tobacco plant. The absence of a sewage disposal plant is shown in the lowering of the plankton population of the Miami River as it passes the city. Exceptions to this generalization are shown in the curves of August 3, 31, and September 14. The reasons for this are not clear, but it may be pointed out that this is the period of low water and slow flow, and Miamisburg is a relatively small town.

Of the upstream samples included in the figure for September 14 (Figure 4), Tipp City, with a secondary sewage treatment plant under construction (1939) to serve 2,500 people, raised the plankton volume; Troy, with a chemical precipitation sewage plant under construction to serve 9,800 people, depresses the plankton population; Piqua, with a chemical precipitation sewage plant under construction (1939) to serve 15,800 people, and with a brewery, a cannery and a meat packing house, causes a slight depression of the plankton recorded at that location.

Sidney has a sewered population of 9,500, but no treatment plant. In addition, creameries, a brewery and a meat packing house supply a heavy industrial load. The meaning of the sharp peak of diatoms at this point is not clear. It may be indicative that one genus of diatom in particular in involved, _Navicula_.

The heavy plankton noticeable in the samples from above Miamisburg, resulting in a considerable volume of Class II planktonts below Miamisburg, in addition to the contribution from that city, must be attributed to the influent from the Dayton urban area, at about mile 85.

The flora and fauna of the Miami are abundant in species and numbers. This is especially true at all stations below Dayton and is due without doubt to heavy pollution load from the cities situated along the stream. These communities are discharging wastes into the stream at close intervals. The river does not recover from one heavy pollution loading before the next load of pollution is received. It is, therefore, difficult to study any one city separately and determine to what degree it affects the stream.

Samples collected during July and August indicate that the Mad River, which joins the Miami above Dayton, is a clear stream, as shown by the lack of organisms other than diatoms. Good trout fishing is reported in this stream at West Liberty. The Stillwater, another tributary which joins the main stream at Dayton, shows heavy pollution at Englewood, where a sample was taken on July 24. This may be due to accumulation of end products from the sewage of towns further upstream. Twin Creek and Seven Mile Creek, which are clear tributaries, enter the Miami at Franklin and Hamilton respectively. Four Mile Creek, which is polluted at Oxford, enters the Miami at mile 38.0.

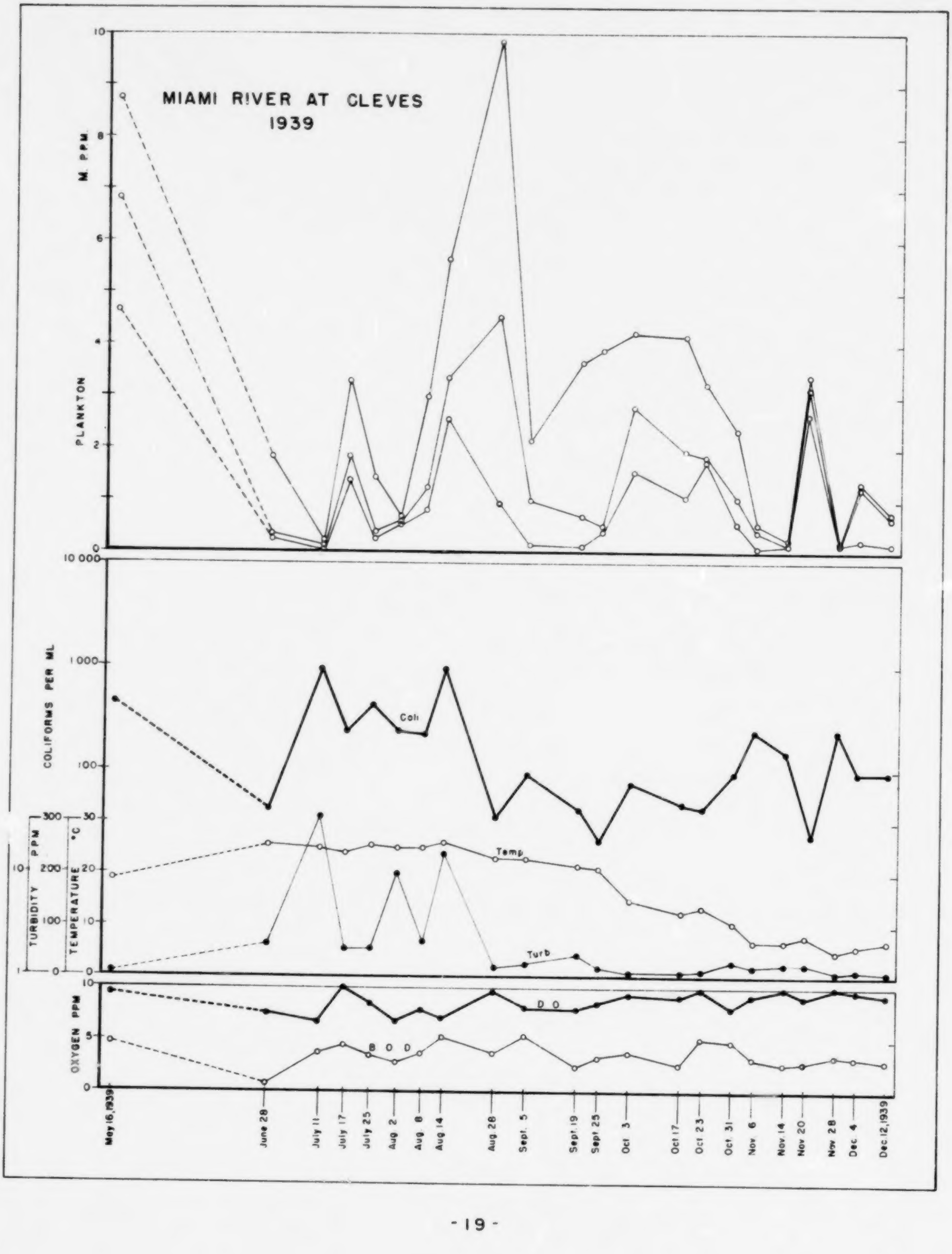
The Whitewater River, which enters the Miami above Cleves, contained large numbers of Euglenophyceae below Harrison, and in the East Fork above Brookville, indicating heavy pollution at these points.

Little Miami River

The Little Miami River has its source in Clark County, Ohio, southeast of Springfield, and flows in a southwesterly direction for 100 miles. It joins the Ohio River within the city limits of Cincinnati, Ohio. The entire drainage basin lies southeast of the Miami watershed and drains an areas of 1,755 square miles. The headwaters have an elevation of 1,150 feet and the river gradient averages about 6.5 feet per mile.

Agriculture is the chief industry throughout the Little Miami Basin. Very little manufacturing is done. Seasonal canning of truck crops, with the waste products entering the

Fig. 2


MIAMI RIVER AT CLEVES
1939
PLANKTON
M. P.P.M.
10
8
6
4
2
0
10 000
1 000
100
COLIFORMS PER ML
Coli
300
200
100
0
30
20
10
0
10
1
TURBIDITY P.P.M.
TEMPERATURE °C
Temp
Turb
OXYGEN PPM
D O
B O D
10
5
0
May 16,1939
June 28
July 11
July 17
July 25
Aug 2
Aug 8
Aug 14
Aug 28
Sept. 5
Sept. 19
Sept 25
Oct 3
Oct 17
Oct 23
Oct. 31
Nov 6
Nov 14
Nov 20
Nov 28
Dec 4
Dec 12,1939

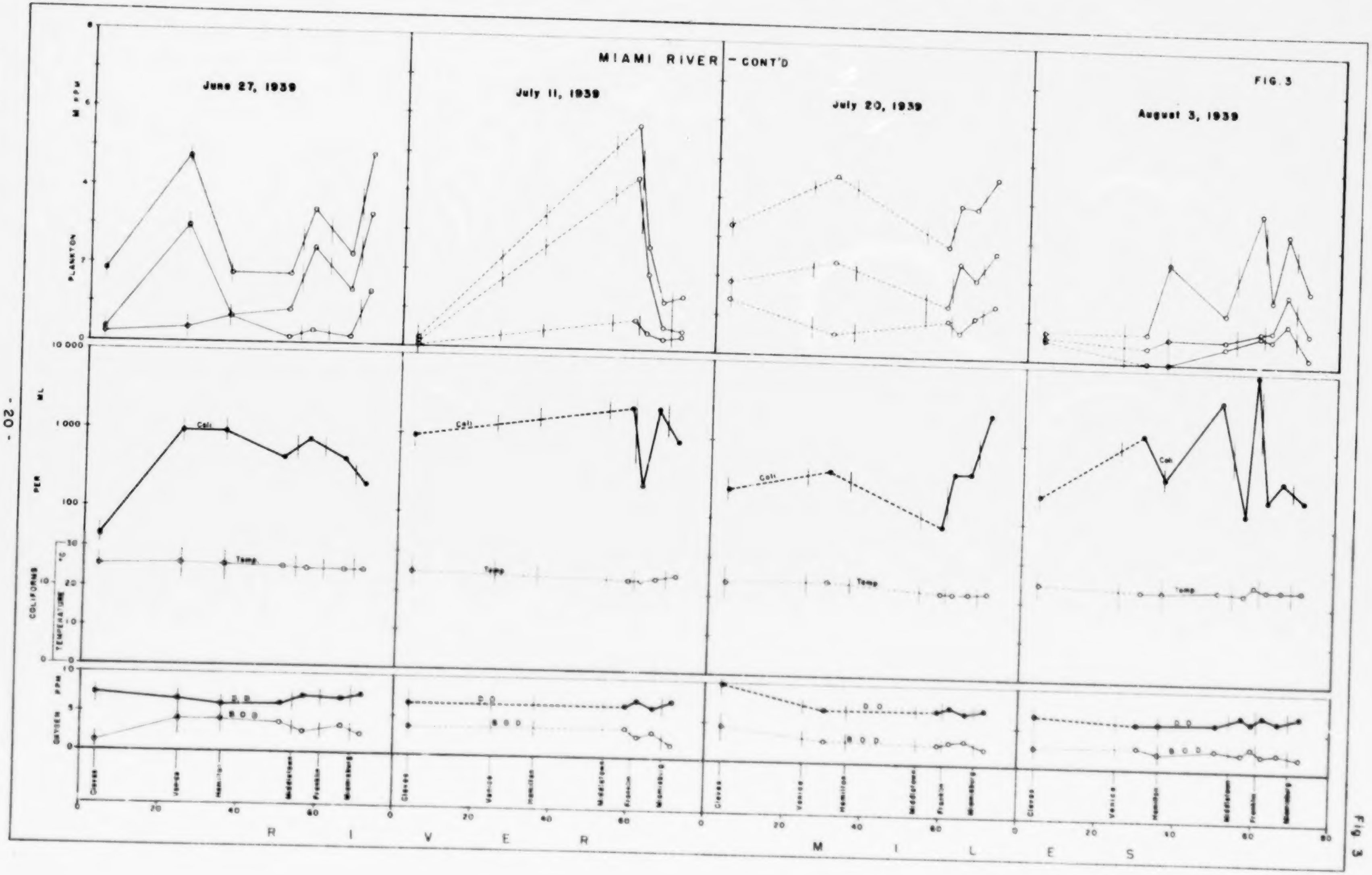
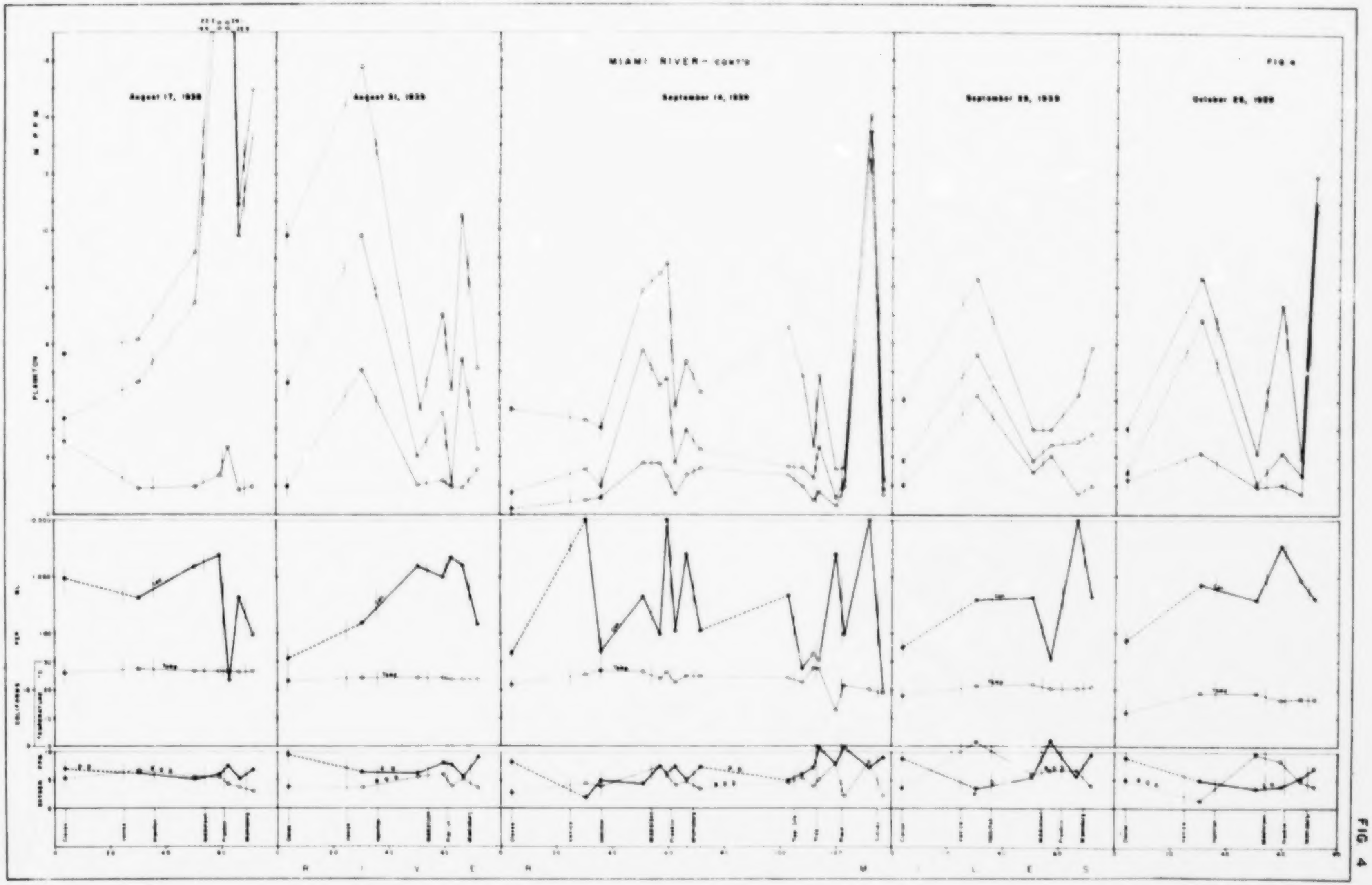

MIAMI RIVER - CONT'D
FIG. 3
June 27, 1939
July 11, 1939
July 20, 1939
August 3, 1939
M PPM
PLANKTON
0
2
4
6
8
10 000
1000
100
COLIFORMS PER ML
TEMPERATURE °C
30
20
10
0
Coli
Temp.
OXYGEN PPM
10
5
0
D.O.
B.O.D.
Cleves
Venice
Hamilton
Middletown
Franklin
Miamisburg
0
20
40
60
80
R I V E R M I L E S

Fig 3

FIG. 4


MIAMI RIVER - CONT'D
FIG. 4
August 17, 1939
August 31, 1939
September 14, 1939
September 28, 1939
October 26, 1939
N P.P.M.
PLANKTON
COLIFORMS PER ML
TEMPERATURE °C
OXYGEN PPM
Col.
Temp.
D.O.
B.O.D.
10,000
1,000
100
30
20
10
0
20
40
60
R I V E R   M I L E S

river, creates a definite stream pollution problem. The total population of the basin, excluding part of the Cincinnati area, was 135,474 in 1940, of which 24,004 reside in the 41 incorporated communities. The principal communities are Xenia (pop. 10,633), Wilmington (pop. 5,971), and Lebanon (pop. 3,890).

A series of samples was taken at Beechmont on the Little Miami River from May 5 to November 20, 1939, with the exception of a period between June 8 and July 31, at which time heavy rains occurred (Figure 5 and Table 2). The B.O.D. was consistently low until August 15, at which time it showed a slight increase, reaching a peak on September 11, during the low water period. An unexplained drop occurred September 25, followed by a consistent rise up to November 6. A slight drop occurred on November 20. The D.O. also showed a decided drop to 3 p.p.m. on September 25, followed by a constant rise up to November 20, at which time it reached the peak of the season due to low temperature at that time. The coliform organism curve is very uniform along the river from July 31 to November 22.

During the period from July 31 to August 2 the small towns along the stream seemed to have no effect on the plankton population (Figure 6 and Table 2). During the rest of the season, however, the plankton dropped below South Lebanon and there followed, in most cases, a gradual rise to the mouth at Beechmont. However, on November 17 the plankton showed a decided drop below Milford.

During the week of September 22-27 a tremendous rise in the plankton occurred below the mouth of Yellow Springs Creek, due, no doubt, to a heavy pollution load from Yellow Springs.

A series of samples was taken along the East Fork and Turtle Creek, important tributaries of the Little Miami. Batavia and Waynesburg (secondary sewage treatment plant since constructed) discharged a small amount of untreated sewage in the East Fork, which, however, is not sufficient to cause a decrease of plankton but keeps the stream fertilized. Turtle Creek shows clearly the effect of heavy pollution on the plankton of a small stream and the rate of recovery of such a stream. The heavy discharge of sewage from Lebanon (chemical precipitation sewage plant since constructed) on July 19, August 2 and October 22, destroyed most of the phytoplankton in the stream immediately below town, but the plankton was present at South Lebanon about 3.5 miles further downstream.

The same condition occurs on Shawnee Creek. Below Xenia on August 25 it was observed that most of the plankton except

Fig. 5

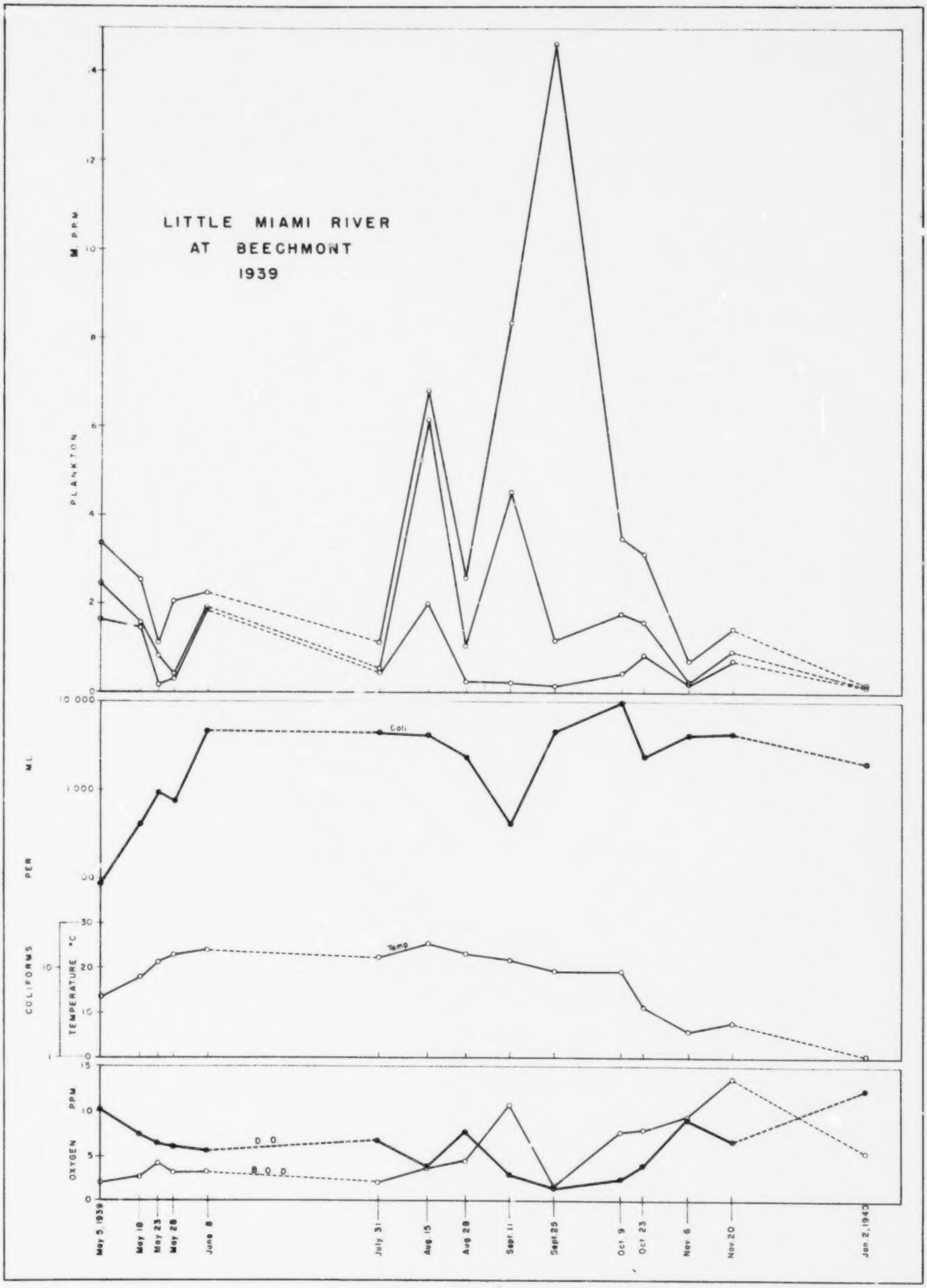
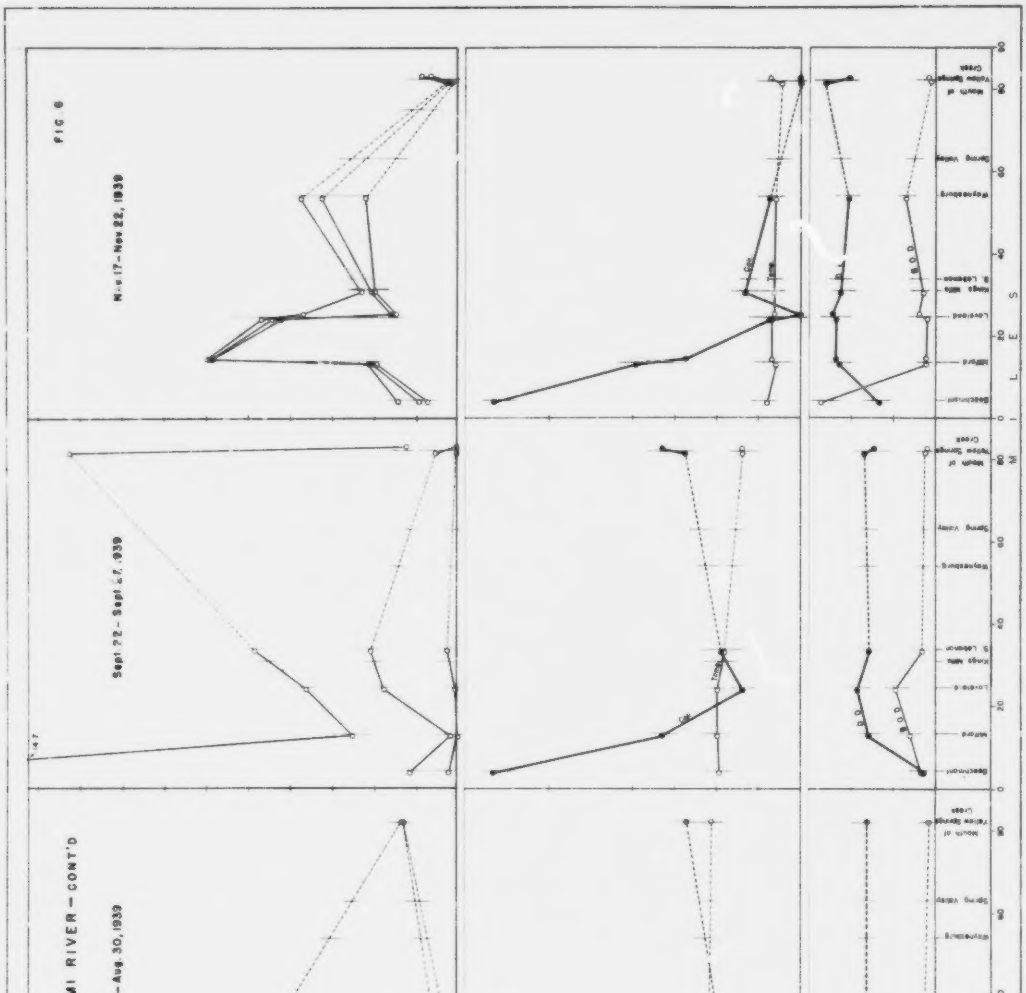

LITTLE MIAMI RIVER
AT BEECHMONT
1939
PLANKTON M. PPM
14
12
10
8
6
4
2
0
COLIFORMS PER ML
10 000
1000
100
10
1
Coli
TEMPERATURE °C
30
20
10
0
Temp
OXYGEN PPM
15
10
5
0
D.O
B.O.D
May 5, 1939
May 18
May 23
May 28
June 8
July 31
Aug 15
Aug 28
Sept 11
Sept 25
Oct 9
Oct 23
Nov 6
Nov 20
Jan 2, 1940

FIG. 6


LITTLE MIAMI RIVER—CONT'D
July 31–Aug. 2, 1939
Aug. 11–Aug. 15, 1939
Aug. 25–Aug. 30, 1939
Sept. 22–Sept. 27, 1939
Nov. 17–Nov. 22, 1939
FIG. 6
PLANKTON M.P.M.
COLIFORMS PER ML
TEMPERATURE °C
OXYGEN P.P.M.
Coli
Temp
D.O.
B.O.D.
Beechmont
Milford
Loveland
Kings Mills
S. Lebanon
Waynesburg
Spring Valley
Mouth of Yellow Springs Creek
R I V E R
M I L E S
0
20
40
60
80
10,000
1,000
100
10
1
30
20
10
0
15
10
5
9.47

the diatoms, Cyclotella and Navicula, were destroyed. A possible discharge from the heavily overloaded treatment plant may have been the cause. The contrasting plankton population of Lytle Creek, below Wilmington, may be due to the chemical precipitation treatment plant.

Licking River

The Licking River rises in the mountains of southeastern Kentucky in Magoffin County, flows in a northwesterly direction across the state and joins the Ohio River between Covington and Newport, opposite Cincinnati, Ohio. The total length is about 320 miles, with a watershed area of 3,670 square miles. Its average slope below Farmers (mile 172.5) is 1.2 feet per mile.

The upper portion of the Licking Basin lies in the mountains. The remainder is in the Bluegrass region. The underlying rocks are principally sandstone, shale and coal. The population of the mountainous region has a density of about 42 per square mile. There are only four incorporated towns in this section, the largest being West Liberty with a population of 573 (1940).

Morehead (pop. 1,901) and Farmers (pop. 296) are the only two incorporated towns in the transition zone between the mountains and the Bluegrass. The Bluegrass section is gently rolling and highly fertile. Four urban communities are in this area: Winchester (pop. 8,954), Paris (pop. 6,697), Cynthiana (pop. 4,840), and Mt. Sterling (pop. 4,782).

Samples at the mouth of the Licking River (Latonia) were taken from May 3 through November 13, 1939. The highest values observed for plankton were during the period from the middle of September to the middle of November (Figure 7, Table 3). The September peak was composed largely of the diatom, Cyclotella, while the peak of November 6 is due mainly to Chlamydomonas. Large numbers of Chrysococcus were found on November 13.

The depression in the plankton curve on May 25 is due to heavy rains between May 17 and May 25. This is accompanied by an increase in the coliform organisms that may have been washed into the river. The coliform count was very low for the remainder of the period of observation. The B.O.D. values were all below 2.5 p.p.m., and the D.O. curve seems to follow the influence of temperature more than any other single feature. The nearest point of any considerable pollution on the Licking

Fig. 7

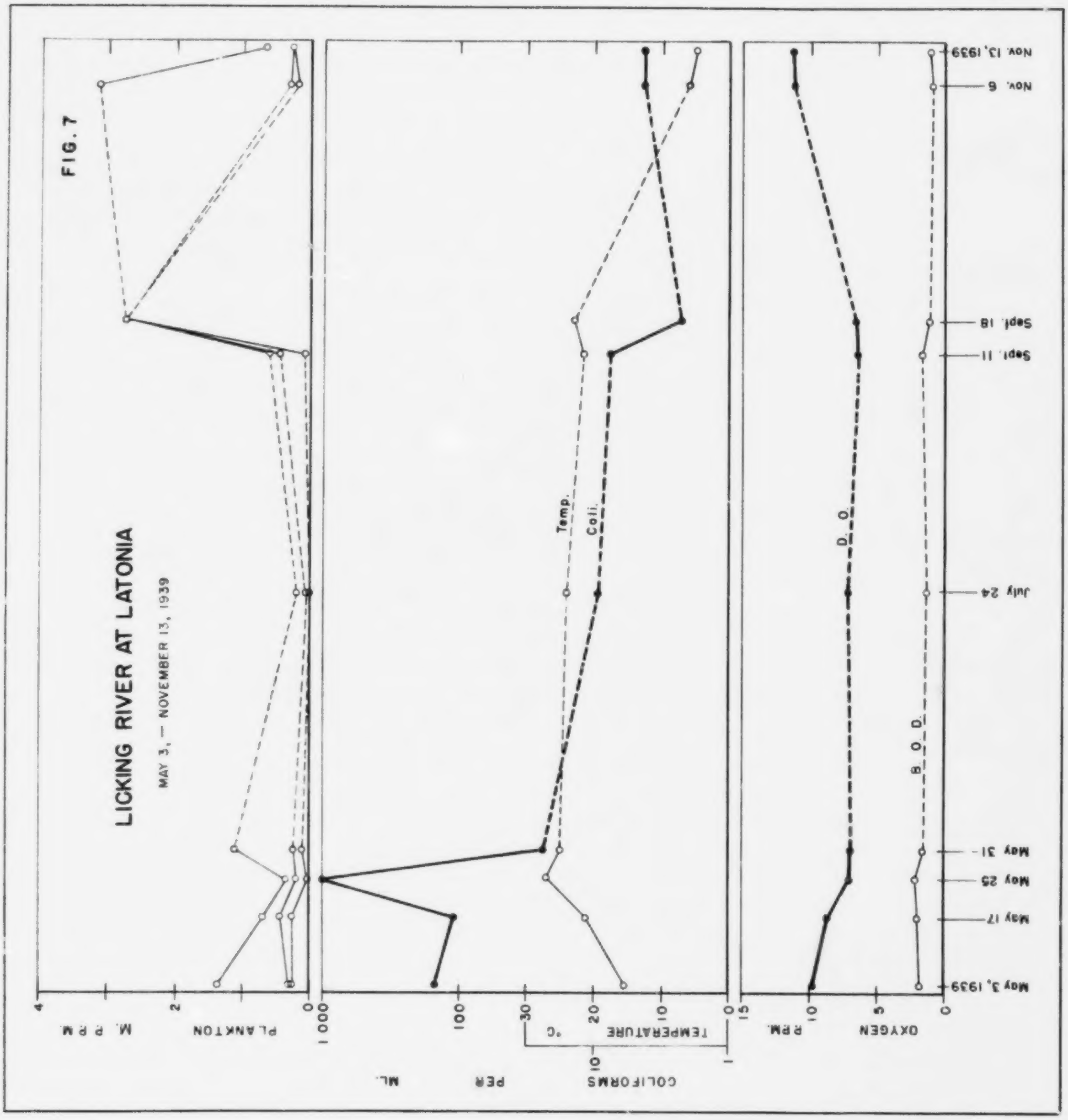


FIG. 7
LICKING RIVER AT LATONIA
MAY 3, — NOVEMBER 13, 1939
PLANKTON
M. P.P.M.
4
2
0
COLIFORMS PER ML.
1 000
100
10
1
TEMPERATURE °C
30
20
10
0
Temp.
Coli.
OXYGEN
P.P.M.
15
10
5
0
D. O.
B. O. D.
May 3, 1939
May 17
May 25
May 31
July 24
Sept. 11
Sept. 18
Nov. 6
Nov. 13, 1939

River is a creamery plant at Falmouth, which is some fifty miles up the river.

Samples were collected on the Licking River from Falmouth (mile 51) to Farmers (mile 172.5). Clayville (mile 82) appears to be a source of slight pollution. The stream also shows some contamination from Blue Lick (mile 100). Fleming Creek, entering a few miles above Blue Lick, is heavily polluted below Flemingsburg, but seems to have recovered before entering the Licking. The large numbers of Chrysococcus in the headwaters above Farmers and in many of the smaller tributaries indicate that these streams are comparatively free from domestic pollution. Some of the smaller creeks (runs) at Salyersville are contaminated with acid mine drainage.

The South Fork was studied by examination of samples collected at Falmouth (mile 51), Cynthiana (mile 82), and Lair (mile 87). The results indicate that these towns are sources of heavy pollution. Hinkston and Stoner Creeks are heavily polluted (septic) below Mt. Sterling and Paris (secondary treatment plant under construction 1939), respectively.

A study of the fishes of the Licking River was made by Welter.(4) He lists a total of 70 species, mostly minnows, shiners, catfish and suckers which are widely distributed in the upper region of the watershed. Various species of bass and sunfish are reported from the main stream at Farmers and Triplet, and from Fleming and Beaver Creeks.

Kentucky River

The Kentucky River rises in the mountainous region of the southeastern portion of Kentucky and flows in a general northwesterly direction to its junction with the Ohio River at Carrollton. The river is formed by the confluence of the Middle, North and South Forks near St. Helena, in Lee County. The three forks rise in Clay, Leslie and Letcher counties, respectively, which lie in the Cumberland Plateau near the Virginia border. The length of the main stream from Carrollton to the junction of the North and Middle Forks is 259 miles. The watershed area is 6,940 square miles. The average slope below Beattyville (mile 255) is about 0.9 feet per mile.

The Kentucky River headwaters are located in an important coal region. Many of the smaller tributaries are heavily polluted with acid drainage from coal mines, giving the water and bottoms of the streams a rusty appearance. This region is subject to heavy rains during the summer, and flash floods are common.

The river has carved a deep gorge of unusual beauty through limestone and shale for many miles of its course, forming the "Palisades of Kentucky" at High Bridge, 117 miles above Carrollton. The mountainous region gives way to beautiful rolling hills forming the well-known "Bluegrass" region around Lexington, through which the river meanders to the Ohio. The fertility of the soils is due to the phosphate nature of the limestone from which the soils are derived.

Population distribution is determined by the geological characteristics of the basin. There are many scattered towns of a few hundred inhabitants in the coal region, but the largest concentration of population is located in the Bluegrass region around Lexington which has a population of 49,304 (1940). Frankfort (pop. 11,492), the state capital, is located on the river, 66 miles above its mouth.

The Kentucky River has been improved for navigation by the construction of fourteen locks and dams from Carrollton to Beattyville.

A series of samples was taken at the mouth of the Kentucky River at Carrollton, from May 2 through November 30, 1939, (Figure 8 and Table 4). From June 9 through September 1, the river was in a very turbulent condition and only a few samples were taken. Following the first of September, the turbidity remained at a low level. The numbers of coliform organisms found at the sampling point were extremely low. The B.O.D. approached 3 p.p.m. before the turbidity increased in the late spring, and was in the neighborhood of 2 p.p.m. at certain times during the summer, showing no correlation with the numbers of the coliform organisms. It is interesting to note that considerable plankton was found in the stream even at times of rather high turbidity. There was a sharp peak of plankton about September 7, due, for the most part, to a bloom of large Pandorina which quickly disappeared. At the termination of this bloom the plankton sank to 0.05 M.p.p.m. or less and remained at this low level for the rest of the period of observation. The plankton curves give an impression that a limited amount of nutrient material was present and was exhausted by the bloom of Pandorina mentioned above.

The usual low level of dissolved oxygen during the hot summer months shows a rise at the time of the Pandorina bloom. There is another rise at the advent of lower temperatures which may be ascribed to the greater solubility of oxygen under these conditions.

Fig 8

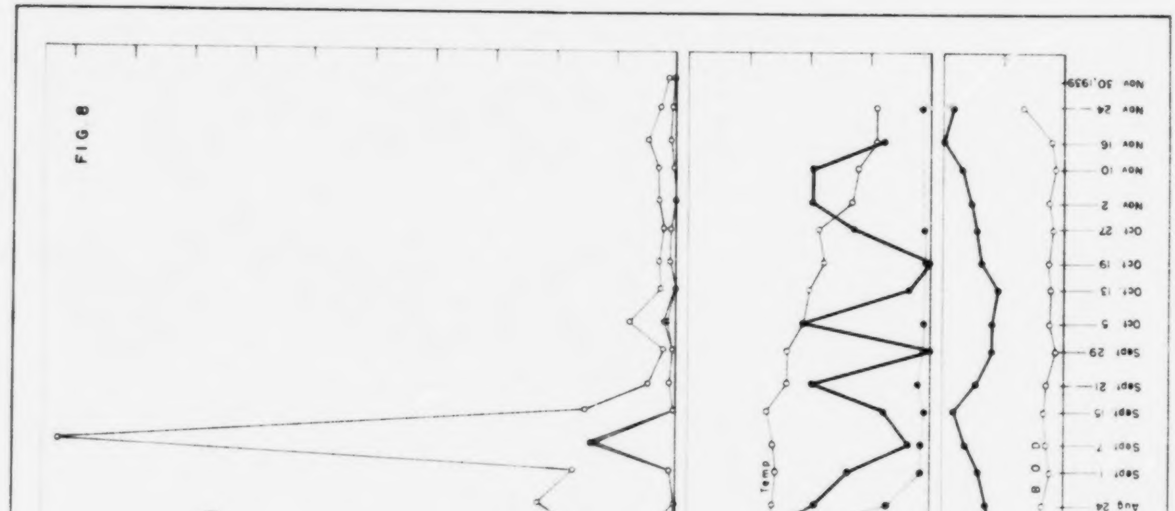


FIG 8
KENTUCKY RIVER AT CARROLLTON
MAY 2, — NOVEMBER 30, 1939
PLANKTON
M. P.P.M.
0
2
4
6
8
10
TEMPERATURE °C.
0
10
20
30
40
TURBIDITY PPM
0
100
200
300
400
COLIFORMS PPM
100
OXYGEN PPM
0
5
10
Temp
Coli
Turb
557
D.O.
B.O.D.
May 2,1939
May 10
June 1
June 9
Aug 4
Aug 18
Aug 24
Sept 1
Sept 7
Sept 15
Sept 21
Sept 29
Oct 5
Oct 13
Oct 19
Oct 27
Nov 2
Nov 10
Nov 16
Nov 24
Nov 30,1939

The Kentucky River shows an almost complete absence of Class II organisms, except for early spring, and shows an occasional flare of diatoms. The characteristic features of the plankton in the Kentucky River involve the large numbers of certain Class I organisms which are found. Samples from the upper portion of the river, especially of the main branch, show extremely high numbers of Chrysophyceae, while samples from certain of the lower portions of the river (Frankfort and below) show large numbers of diatoms. With one or two local exceptions, Class II organisms are very scarce.

"Good Fishing" is reported locally on the Kentucky River from Carrollton to Gratz, and considerable commercial fishing is being done at Gratz, 29 miles above the mouth. Several species were reported, such as carp, catfish, pike, bass and perch. Local inhabitants reported that there are no game or food fishes in the river at Irvine (mile 218).

Big Sandy River

The Big Sandy is formed by the confluence of Levisa and Tug Forks at Louisa, 27 miles above the mouth. The main river and 94 miles of the Tug Fork form the boundary between Kentucky and West Virginia. The entire basin comprises an area of about 4,280 square miles, of which 2,280 are in Kentucky, 1,015 in Virginia, and 985 in West Virginia. The topography is largely mountainous or hilly, and the underlying rocks are composed of sandstone, shale and coal. There is considerable coal mining on the headwaters, and acid mine drainage and coal washings are important sources of pollution. The area was originally covered with hardwood forests, but most of them have been cut away. The soils are generally thin and infertile, and the slopes are too steep for successful agriculture. The small amount of good farming land is located along the streams and forms a very small percentage of the total area.

The average slope of the Big Sandy below Louisa is 1.1 feet per mile. The slope of Tug Fork is 12.2 feet per mile near the headwaters. The slope of Levisa Fork is about 1.3. The stream has been improved for navigation by the construction of three dams between the mouth and Louisa, and one dam on each fork.

The population of the Big Sandy Basin in 1940 was 411,905, of which 31,185 lived in towns of more than 2,500 people. About 35,000 lived in small incorporated towns, and a large but unknown number were in unincorporated mining camps. The density of population was 97 per square mile.

The important towns along the Tug Fork are Welch, population 6,264 (mile 160), and Williamson, population 8,366 (mile 84). The only town of urban size on Levisa Fork is Pikeville, population 4,185 (mile 115.7).

A series of samples was taken 0.3 miles above the mouth of the Big Sandy during the period from June 14 to November 27, 1939, (Figure 9 and Table 5). The B.O.D. at this location was less than 2.5 p.p.m. during the entire period of observation. The D.O. was fairly constant at about 6.5 p.p.m. following the middle of September, although during the time preceding this date there were some irregularities. During the period of decreasing temperatures, after the middle of October, there was a slight but constant rise in both the B.O.D. and the number of coliform organisms, which follows inversely the trend of the temperature.

There are several distinctive features of the plankton population at this location. There is an almost complete absence of diatoms, for the most part, and an unusually large and constant volume of Class II organisms. The low coliform organism counts are perhaps evidence of the relatively clean nature of the stream at the sampling point. This may be substantiated by the rise in plankton paralleling the rise in coliform organisms from September 1 to October 24. The depression in the plankton curve on October 12 is due to heavy rains which fell generally throughout the basin. The depression at the mouth on September 14 may perhaps be related to rains which fell at scattered points on September 5. There is a noticeable tendency for the plankton to survive after the B.O.D. and coliform organism values have dropped.

The deficiency of diatoms at this sampling point seems characteristic of the Big Sandy River as a whole, as data from points upstream seem to show. Diatoms are numerous only in that portion of the Tug Fork in the vicinity of Welch and Iaeger. The Big Sandy at the mouth receives wastes from a refinery a short distance upstream but this is apparently not the cause of the local absence of diatoms. Residents report that catfish and carp are present but that their flesh is unfit for food due to the odor and taste of the petroleum constituents.

Samples taken at points in the upper portion of the watershed show a predominance of Class I forms except immediately below sources of pollution.

Fig. 9

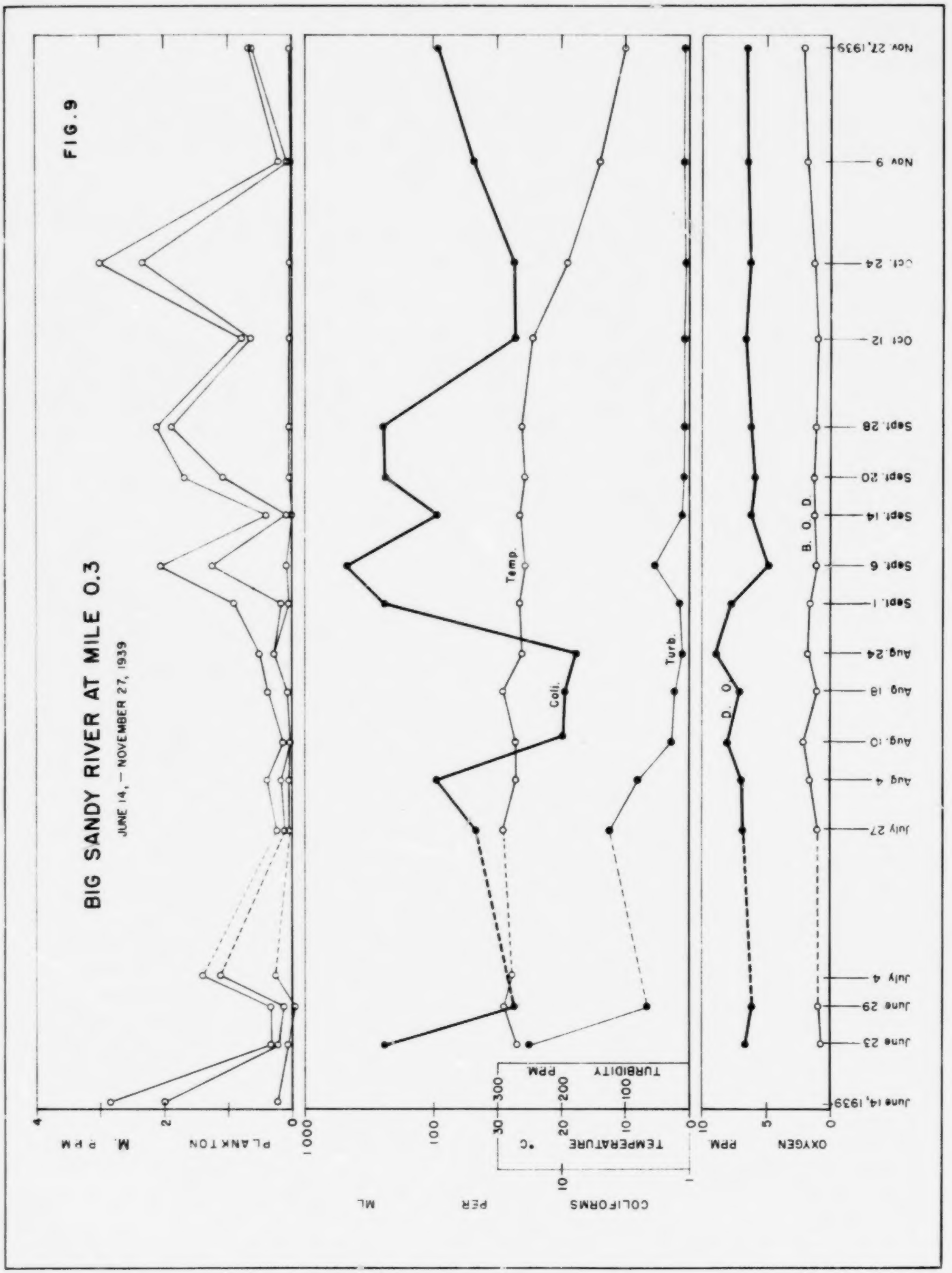


FIG. 9
BIG SANDY RIVER AT MILE 0.3
JUNE 14, — NOVEMBER 27, 1939
PLANKTON M. P P M
COLIFORMS PER ML
TEMPERATURE °C
TURBIDITY PPM
OXYGEN PPM.
Temp.
Coli.
Turb.
D. O.
B. O. D.
4
2
0
1000
100
10
1
30
20
10
0
300
200
100
10
5
0
June 14, 1939
June 23
June 29
July 4
July 27
Aug 4
Aug. 10
Aug 18
Aug. 24
Sept. 1
Sept. 6
Sept. 14
Sept. 20
Sept. 28
Oct. 12
Oct. 24
Nov 9
Nov. 27, 1939

Little Sandy River

The Little Sandy River lies in the northeastern portion of Kentucky. It rises in the hills of Elliott County, and flows through steep, narrow valleys in a northeasterly direction. It joins the Ohio River below Greenup, Kentucky. Small coal mines are operated in the headwaters and a number of abandoned mines add acid drainage to many of the small tributaries. Sandy Hook (pop. 155), and Grayson (pop. 1,176), are the most important towns on the stream. There are, however, several communities between Sandy Hook and Grayson that empty untreated wastes directly into the river.

Samples were taken at the mouth of the Little Sandy River (mile 0.1) between June 14 and November 24, 1939, and a few were taken above and below Grayson (mile 28) in September, October and November (Figure 10 and Table 6). Until early in August, the water of Little Sandy was rather turbid and the B.O.D. and coliform organism values were low. It is during this period that most of the Class II organisms appeared in the plankton samples at the mouth of the river. Commencing with the sample of August 11, there is a rise in the general level of the coliform organisms and, to a lesser extent, of the B.O.D. In connection with these data for the mouth of the river, it is to be noted that samples in the region of Grayson on September 8 and 22 show fair numbers of Class II organisms below Grayson, in contrast to none above the town. Class I organisms, with the exception of Cryptomonas erosa, are scarce at the mouth of the river, while the samples in the vicinity of Grayson show considerable numbers of Chrysococcus and Dinobryon. As there is no consistent difference between the Chrysococcus population immediately above and below Grayson and as the stream is swift here, it seems that a certain distance is necessary for the effect of the pollution introduced by the community to be felt in the plankton population.

It is to be noted that in one sample, that of September 8, Dinobryon is present in considerable quantity below Grayson, while it is absent above the town. Aside from samples which include an occasional large ciliate, the plankton volume found at the mouth of the river was usually less than 0.5 M.p.p.m. The samples taken in the vicinity of Grayson were of the same order of magnitude.

Guyandot River

The Guyandot River rises in Wyoming County, southern West Virginia, and flows northwesterly, discharging into the Ohio River at Huntington, West Virginia. The length of the

Fig. 10

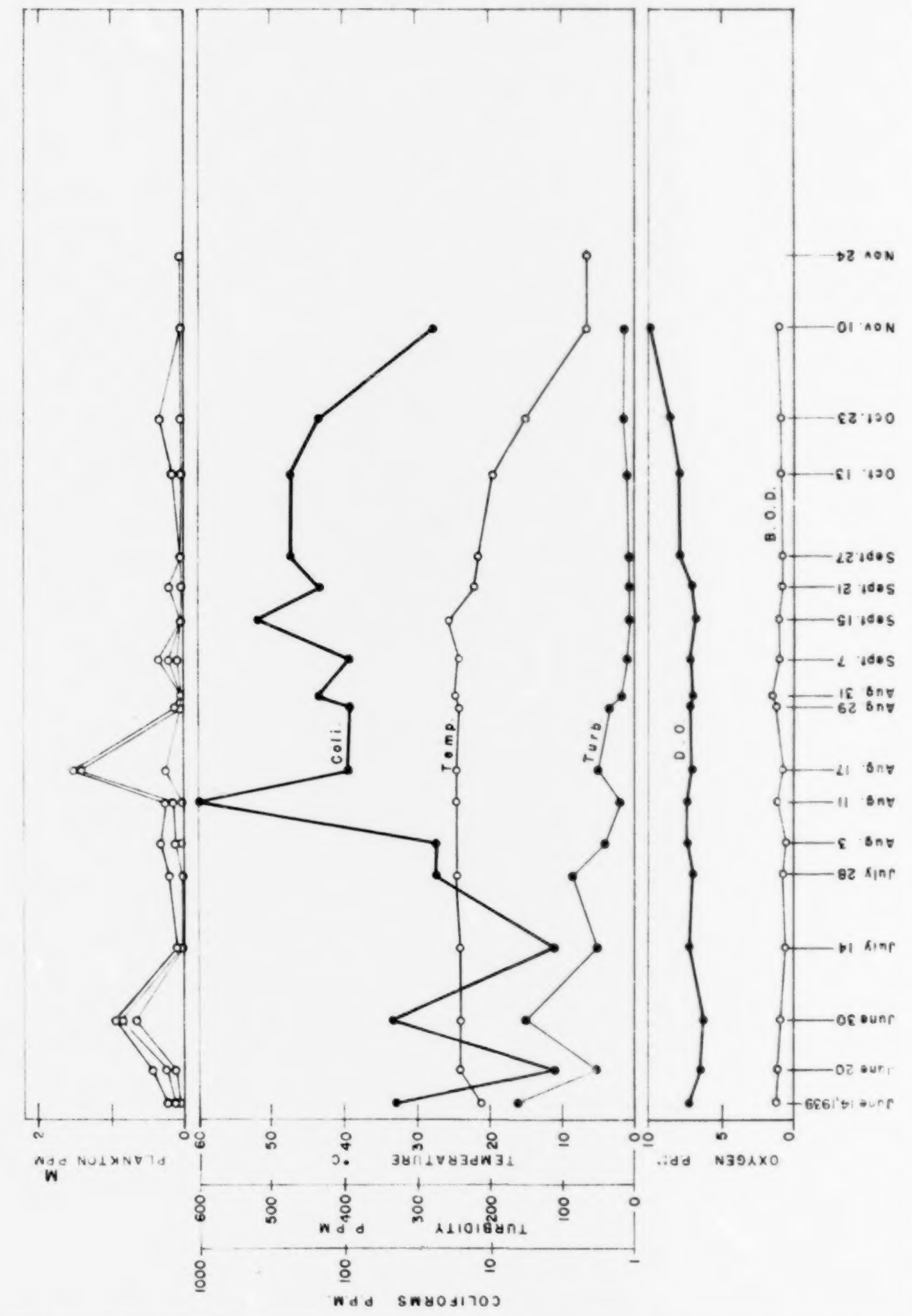


FIG. 10

LITTLE SANDY RIVER
Near Mouth
JUNE 14,-NOV 24,1939

river is about 166 miles. The stream drains an area of 1,670 square miles of hilly and mountainous country between the Kanawha and Big Sandy Rivers. The area is underlaid by one of the largest bituminous coal deposits in the country. Natural gas occurs in the northern part of the basin.

Below Logan (mile 81), the stream has an average slope of about 1.8 feet per mile, while above Logan the slope averages 11.2 feet per mile. The flow of water is fairly uniform for the lower thirty miles, but above this the stream is a succession of pools and shoals.

The basin is a part of the Allegheny Plateau, and the poor soil and steep slopes make the land unsuitable for agriculture. Less than one-fourth of the land is cleared. The population of the Guyandot Basin in 1940 was 148,257. There are only ten incorporated towns in the basin and only two of these, Logan (pop. 5,166), and Mullens (pop. 3,020), has more than 2,500 people.

Samples were taken at irregular intervals at the mouth of the Guyandot River at Huntington (mile 0.6), from June 14 through November 27, 1939. The stream, at this point, is practically a pool from the backwater of Dam 28 in the Ohio River. At various times during the summer the water was colored by dye from an industrial plant in Huntington. A very heavy concentration of a blue dye appeared in a sample taken October 24, and the same dye appeared in the Ohio River sample taken below Greenup, Kentucky. It is difficult at the present time to state the effect of this dye upon plankton. The plankton volume was low during the period of observation. After August 14 it was less than 0.5 M.p.p.m. and usually less than 0.3 M.p.p.m. (Figure 11 and Table 7).

In contrast with the low plankton, the coliform organism count is extremely high and the B.O.D. also reaches high values. At times of high temperatures and high B.O.D., the dissolved oxygen is greatly reduced, reaching the low value of 0.08 p.p.m. on September 28.

The three peaks of the turbidity curve coincide with the three slight rises of the plankton curve and may indicate a flushing down of plankton from the higher, less polluted regions of the river. It should be pointed out that the B.O.D. does not reach the same relatively high values, for the most part, as the coliform organism count, indicating that it is possible to have domestic pollution of a type which constitutes a serious public health hazard without being indicated by a high B.O.D.

Fig. 11

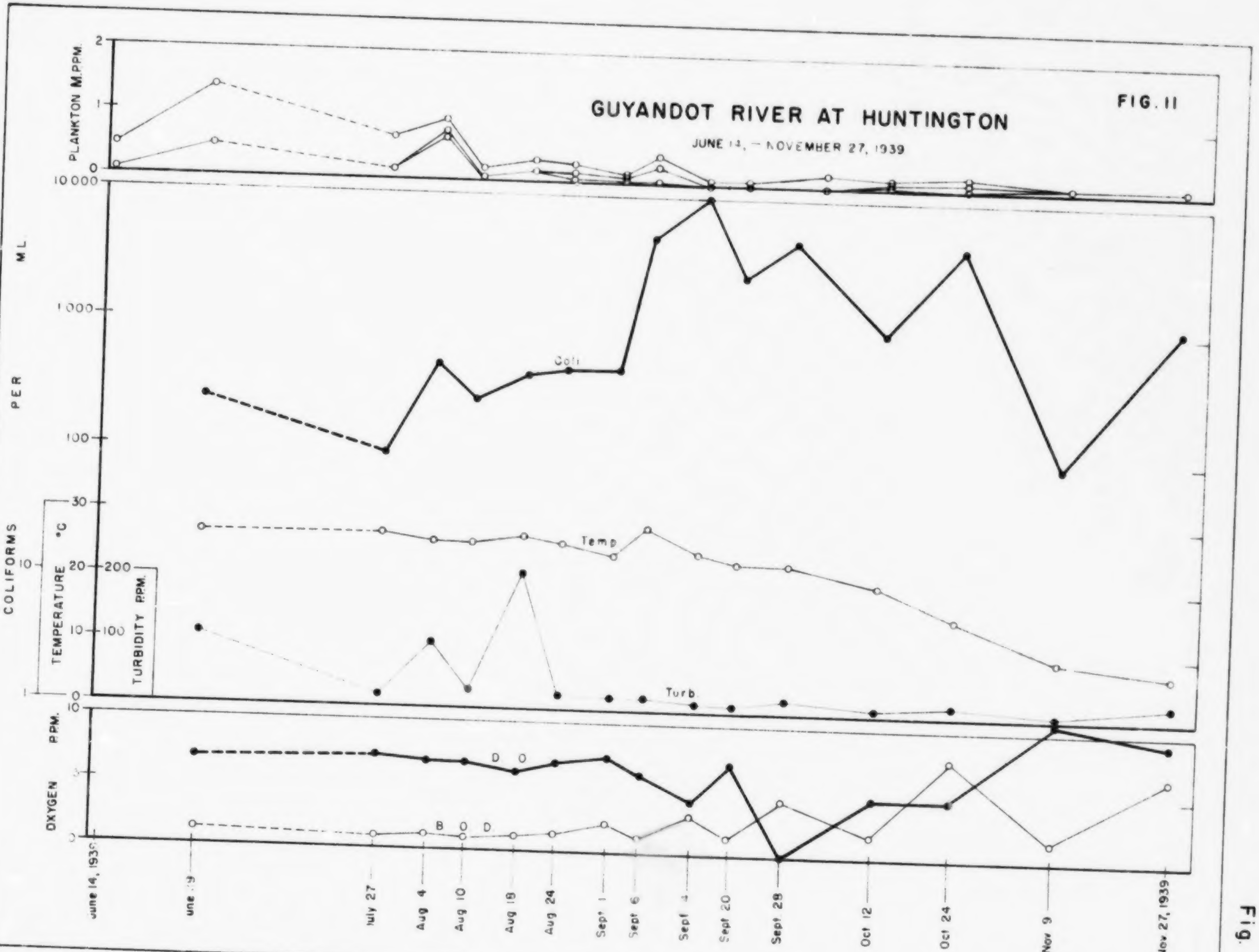


FIG. 11

GUYANDOT RIVER AT HUNTINGTON

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The stream between Huntington and Gilbert (mile 111.3) contains a high number of Chrysophyceae. There was practically no aquatic life in the stream at Pineville, Itman and Mullens, due to the heavy discharge from coal washeries. In October and November the water was black with small particles of coal. Likewise, the small tributeries in the headwaters, Buffalo, Island and Clear Forks, were devoid of life due to the discharge of coal mine drainage.

Kanawha River

The Kanawha River, with a drainage basin of 12,300 square miles, is formed by the union of the Gauley and New Rivers in the southwestern part of West Virginia and flows in a northwesterly direction, emptying into the Ohio River at Point Pleasant, West Virginia. The total length from the mouth to the junction of the New and Gauley Rivers is about 97 miles. The average slope of the upper portion is about 2 feet per mile, decreasing to 0.37 feet per mile at the mouth. Navigation has been improved for 90 miles by the construction of three locks and dams.

The upper three-fourths of the basin lies in mountainous territory, and less than one-twelfth of the entire basin is tillable. The total population of the basin is 834,845 (1940). Natural resources in the form of bituminous coal, oil and natural gas, have attracted a number of chemical plants to the Kanawha valley and the area is becoming one of the important chemical producing centers in the country.

The principal tributaries are the New, Gauley and Elk Rivers. The Elk is highly polluted by oil refineries and gas plants.

Scattered samples taken at Point Pleasant on the Kanawha River (mile 0.6) from August through November, 1939, show an exceptionally low coliform organism count and very low B.O.D., indicating that the stream at this point is undoubtedly quite clean (Table 8). This is confirmed by the absence of Class II organisms. The total plankton population is also low, although the sample of August 10 showed very large numbers of *Cryptomonas*, which persisted to a lesser extent in later samples. *Chrysococcus* was relatively scarce.

Samples throughout the month of July at scattered points up the river as far as Montgomery (mile 85) show a somewhat higher plankton volume, with occasional Class II organisms appearing. Cryptomonas was high for some thirty miles or more up the river during this period. In October, samples from points in the headwaters of the river showed very little plankton, mostly Cryptomonas, Chrysococcus and Chlamydomonas.

Upper Third

Monongahela River

The Monongahela River is formed by the junction of the West Fork and Tygart Rivers about one mile south of Fairmont, West Virginia. It flows through Pennsylvania, uniting with the Allegheny River at Pittsburgh to form the Ohio River. Its length is about 128 miles and it drains an area of 7,380 square miles. The average slope in the upper part is 2.1 feet per mile, which later drops to about 0.7 feet per mile. Fourteen locks and dams have been constructed along the river.

The Monongahela River is subject to an enormous amount of industrial pollution. A great portion of this pollution is acid waste of one type or another. During the latter part of June, 1940, while the water was still fairly high and rains were frequent, the acidity of the stream in the fifty-mile region between Morgantown (mile 100.9) and Roscoe (mile 48.5) hovered in the vicinity of pH 6. On either side of this intermediate region, the pH fell off rapidly, being approximately 3.7 at Pittsburgh (mile 0) and at Worthington on West Fork (mile 136). During this period the D.O. was fairly high. Plankton and chemical samples were available for August 19 from Dam 8 at mile 90 down to Dam 2 at mile 9 (Table 9). At this time the pH of the whole 80 miles lay between 3.3 and 3.7. Coliform organisms were practically absent and the B.O.D. was about 0.65 p.p.m. or less. The plankton volume was low and consisted almost exclusively of Closteriopsis. A few diatoms were found locally. Plankton samples taken late in June showed many Navicula, some Cymbella, Dinobryon, and some unidentifiable green flagellates in the vicinity of Morgantown.

Fish studies were made during the latter part of June and the first part of July. In the upper region, on the West Fork of the river, at Good Hope, W. Va., there is a fair fish population, consisting of long-eared sunfish, smallmouth bass, redhorse suckers and rock bass, together with a rather large number of various shiners and minnows. Only one shiner each was found at Rivesville and Worthington. From there (mile 136) to the mouth of the Monongahela, only an occasional fish (shiner) was collected, except near the mouth of a nonacid tributary. Many of these nonacid tributaries contribute a good mixed fish fauna, but the fish apparently do not become established in the Monongahela. Many catfish, carp and suckers, as well as some of the game fish, were found dead or dying below the entrances of such tributaries.

No fish, with the exception of one small sunfish and one small catfish, were taken on the Tygart below Grafton Reservoir, although the state had stocked the reservoir with game fishes.

Allegheny River

The Allegheny River has its source in north-central Pennsylvania. It flows in a northwestern direction into the state of New York, turns and flows back into Pennsylvania. From here its course is southwest to Pittsburgh, where it unites with the Monongahela River to form the Ohio. Its length is about 325 miles. The average slope below Olean, New York, (mile 259), is 2.7 feet per mile. The drainage area is about 11,730 square miles, of which 9,775 are in Pennsylvania and 1,955 are in New York. This area lies in the Appalachian Plateau and is, for the most part, hilly or mountainous. The river has been improved for navigation by the construction of eight locks and dams, to mile 61. The population of the basin (1940), exclusive of the City of Pittsburgh, is approximately 1,237,000. The distribution between urban and rural population, also exclusive of Pittsburgh, is 42 per cent and 58 per cent, respectively. The population (1940) of Pittsburgh is 671,659, of which slightly over one-third is in the Allegheny River Basin.

In contrast to the Monongahela River, the Allegheny, above mile 50, shows a pH 7 or higher. Below this point a certain amount of acid pollution occurs.

Samples were taken of the main stream during the month of August, 1940, (Table 10). Following downstream, the Tionesta River (mile 154) seems to be the source of the first heavy pollution. From the chemical data, there would seem to be some acid pollution as well as an introduction of organic material. The D.O. drops sharply to about 5 p.p.m. The reserve alkalinity drops and the pH is about 7.4. These effects may be due to a tannery located on the Tionesta.

There is a plankton population below the Tionesta of about 1.5 p.p.m. Diatoms are plentiful and Class II organisms are infrequent. From Kennerdale (mile 110) down, the plankton is composed almost entirely of Class I organisms, especially diatoms.

The irregularities of the plankton volume figures are accentuated by numbers of the large diatom Surirella at miles 14, 50 and 70. It is striking that at Brackenridge (mile 22, no plankton whatever was found. B.O.D. values of about 1 p.p.m. in this region of the stream above mile 50 are, in general, higher than in the acid stream below. At Pittsburgh a large number of coliform organisms are introduced into the river with a relatively slight change in the B.O.D.

The Allegheny River, from the headwaters to Kittanning (mile 46), supports a fair mixed fish population. Various suckers, crappies, bass and sunfish were collected at Warren, Pennsylvania. Further down the stream at East Brady, bass, hogmolly and quillback suckers were taken. At Mosgrove, suckers, walleyed pike, trout-perch and smallmouth bass were fairly abundant.

The Clarion River supports a large fish population consisting of yellow perch, small- and largemouth bass, rock bass, catfish, suckers, carp and numerous snapping turtles. This stream is colored black from tannery and paper mill wastes in the headwaters. Fish caught in this stream could not be used as food, as their flesh was tainted from the chemicals. The Tionesta, also polluted by paper and tannery wastes, supports a large fish population. Many of the streams tributary to the Clarion and the Tionesta contain trout, but no trout were taken in the main stream. The Kiskiminitas River is too acid from mine drainage to support fish.

Muskingum River

The Muskingum River is formed by the confluence of the Walhonding and Tuscarawas Rivers at Coshocton, Ohio. It flows in a southeasterly direction and empties into the Ohio River at Marietta. Its length is about 110 miles and average slope 1.5 feet per mile. The Muskingum drains an area of 8,040 square miles, comprising about twenty per cent of the entire state of Ohio. The northern and western portions of the basin have been smoothed by glacial action, and the topography is undulating to rolling. Seventy to eighty per cent of the basin is used for agriculture. The rate of flow is controlled by reservoirs in the upper part of the watershed. Eleven locks and dams have been constructed to a distance of 91 miles from the mouth of the river.

The total population of the basin in 1940 was 812,028, about equally distributed between urban and rural inhabitants.

The leading industries are steel, metal products, clay, rubber and paper. Coal is mined to a limited extent in the eastern part of the basin.

The data for the Muskingum River are particularly unsatisfactory as this watershed was subjected to rains during most of the period of study. As a result, plankton samples are scattered in date between the beginning of April and the end of August, 1940. It is unfortunate that the one good series of plankton samples taken on July 19 is unaccompanied by any chemical data. The April samples show diatoms almost exclusively, although the plankton volume is low. These conditions still exist at the mouth of the river early in June. Below Zanesville (mile 75) at this time there is a considerable volume of plankton containing an occasional Euglena or Protozoan but still composed, to a large extent, of diatoms. In July the plankton was somewhat more varied, while in August a sample taken above McConnelsville (mile 48) at Duncan Falls (mile 66.8) showed the plankton well distributed among the different taxonomic groups.

The series of July 19 was taken from Zanesville to below Stockport (mile 39) and indicates the following influences (Table 11). The plankton volume is quite high in the region below Zanesville, dropping somewhat as one approaches Duncan Falls. At Duncan Falls the volume again increases sharply, with an increase in the number of Class II organisms. From Duncan Falls through Gayport and McConnelsville, the volume drops off somewhat, although still maintaining high levels, and a further drop occurs below Stockport. The plateau between Gayport and McConnelsville may be due to an absence of intermediate samples. The watershed supports a good mixed fish population.

Hocking River

The Hocking River, having its source about 35 miles southeast of Columbus, Ohio, empties into the Ohio River at Hockingport, Ohio. Its length is about 100 miles. The average slope above Lancaster (mile 89) is 4.5 feet per mile, and the lower part of this river has a slope of 2.3 feet per mile.

The Hocking River drains an area comprising 1,185 square miles. The population of the basin in 1940 was 113,555. A little more than half the population is urban. The natural resources of this area are coal, clay, natural gas and oil, and farming is the principal industry.

Scattered samples were taken at various points on the Hocking River in late May, June, July and August, 1940. In May, samples taken at Coolville (mile 5) and Guysville (mile 20) showed a plankton largely composed of diatoms, with some Cryptomonas, Chrysococcus, Dinobryon, and an occasional ciliate or Euglena. The most abundant organism was Navicula, a diatom. The plankton at Coolville was rather more abundant than at Guysville.

A sample taken below Athens (mile 35) in late June showed a varied plankton population with considerable numbers of Class II organisms. The plankton at Hockingport (mile 0.1) at the same period was somewhat less abundant and contained fewer Class II organisms and more Class I forms. In July the plankton of the lower river was quite abundant and varied. There were considerable numbers of Class II as well as Class I organisms at Hockingport, Coolville and Guysville. There was little plankton at Nelsonville (mile 53), while the plankton above Logan (mile 67) consisted mainly of diatoms, with some Euglena. Below Sunday Creek (mile 42) the plankton was much reduced, both in kind and number. The most common forms were the diatom, Asterionella, and Oscillatoria, a blue-green alga.

In August a fairly complete series was obtained from below Nelsonville to Hockingport (Table 12). The D.O. during this period was fairly good, with a depression in the values below Athens. The plankton was fairly abundant below Nelsonville, being composed largely of Class II organisms. Between Nelsonville and the region above Athens the plankton volume was sharply decreased. This was undoubtedly due to the influence of Sunday and Monday Creeks, which were pouring water of approximately pH 3 into the main river. A resurgence of the plankton occurs from Athens to Guysville. The depression at Coolville cannot be well explained except as indicating the absence of an immediate source of pollution. At Hockingport the plankton volume was again high, passing 6 M.p.p.m.

Fish collections made during this August trip showed that smallmouth bass were plentiful below Nelsonville and that biological conditions in general seemed good. Hogmolly and shiners of all sizes were present, crayfish were plentiful, and there were many empty mussel shells. However, there was a whitish growth noticeable on the bottom and on the rocks. Above Athens, below the entrance of Sunday and Monday Creeks, fish were less plentiful. Minnows were numerous but bass were found in much smaller numbers and hogmollies were replaced by quillback suckers. The bottom of the stream was of a greenish-black color.

At Coolville fish seemed quite abundant. Many people were fishing on and alongside the dam. The seine caught numerous small catfish, common and quillback suckers, smallmouth bass and hogmollies. In general, these fish were larger than those caught upstream.

Little Kanawha River

The Little Kanawha River rises in the western foothills of the Allegheny Mountains, near the eastern border of West Virginia, and flows north about 160 miles, emptying into the Ohio River at Parkersburg, W. Va. The average slope below Burnsville (mile 122) is about 1.5 feet per mile. The river drains an area of 2,320 square miles.

The basin has been cleared of forests, except above Burnsville, and is devoted to agriculture. Oil and gas fields are located over a considerable portion of this area. There are also local coal deposits in the region of the headwaters. With the exception of oil and gas, there is little industrial development in this basin. The population in 1940 was 92,355, almost entirely rural.

A series of samples was taken along the Little Kanawha River from Glenville (mile 103) to its mouth, late in August, 1940, (Table 13). The plankton at Lock 3 (mile 25) and above is rather low for the most part. The high volumes appearing in the table at miles 28, 80, 101 and 103, are each due to one or two specimens of large diatoms which affect the volume figures considerably.

Creston (mile 48) and Elizabeth (mile 27) seem to be the principal sources of pollution along the upper stream. Below Elizabeth the Hughes River enters at mile 17 and carries only a small volume of plankton. The upper Little Kanawha River has the local reputation of being the best bass water in the state. The stream, at the time of investigation, was low and the volume of water small. Seining conditions on the whole were bad. Net catches consisted mainly of common and redhorse suckers, turtles, and an occasional Kentucky bass. At Creston, where the West Fork enters, fish were relatively plentiful, suckers of various kinds and a few smallmouth bass being noted. The West Fork has a reputation as a good pike stream, having some deep holes from which large fish are occasionally caught. Below Elizabeth, catches consisted of small suckers, sheepshead, mooneyes, crappies and white bass. Seining conditions were unfavorable.

At the time of our visit in August, peculiar conditions were found at the mouth of the river from Dam 1 (mile 4) to the

Ohio. The water was highly turbid and opaque, and there was considerable scum on top. The water coming from the pool above made a distinctly marked area of cleaner water below the dam. In this region fish were actively breaking water, while further below the scum was unbroken. At the East Parkersburg Bridge, the same general conditions prevailed, except that no fish were seen. D.O. determinations showed 0.33 p.p.m. of oxygen at the bridge. Immediately above the dam the oxygen value was 5.9 p.p.m., while at the lower end of the lock wall, in the scum-covered region, the oxygen was 3.3 p.p.m. There were, furthermore, distinct temperature and pH differences between the water above and below the dam, both the acidity and temperature being higher below the dam.

The plankton on this date showed a large bloom of *Pandorina* above the dam and extending into the pool below. The numbers of *Pandorina* at the East Bridge were considerably lower, although still high. These organisms formed the bulk of the plankton population.

According to observers, fish had been dying in the pool for several weeks. Evidence of this was found below the dam where numbers of dead fish were floating and stranded on the shore. These included bass, suckers, mooneyes, shiners, sunfish, crappies, some very large pike, and other large fish no longer identifiable, as well as salamanders and other water creatures, but notably few catfish were found. According to the lockmaster, this fish slaughter has occurred every year under similar weather and low water conditions. In years when a temporary rise occurred in the middle of the season, there would be a recurrence of fish deaths as the water again subsided. Under these lethal conditions the water becomes unfit even for industrial use by the large Viscose plant located at Parkersburg. This plant has an accessory water intake above the dam for use during these periods.

As stated above, very few catfish were found among the material stranded on the bank. However, on August 23, at the East Bridge, it was noted that large numbers of black catfish were seen along the surface of the river, moving very little but occasionally struggling or disappearing temporarily from the surface of the water. It proved possible to catch some of the fish from the shore by means of a dip net. The fish would swim slowly along the surface and go directly into the net without any effort to escape. An occasional very small fish, other than catfish, was seen along the shore, which was apparently able to survive the water conditions temporarily. Measurements showed that there was zero oxygen concentration in the water at that point.

Measurements in the vicinity of the dam showed that the oxygen values had fallen at this point also, being approximately 4.7 p.p.m. above the dam and 2.3 p.p.m. below the dam. The temperature and pH differences between the two sides of the dam still existed. The plankton distribution had changed overnight. The number of *Pandorina* above the dam had dropped, while below the dam it had risen appreciably. This seemed to indicate that there had been a wave of these organisms which had passed over the dam.

Pandorina "blooms" have been found at other times and places and, in general, the evidence is that these blooms raise rather than lower the D.O. In no case have they been found toxic to aquatic life. It is, therefore, clear that the conditions at Parkersburg cannot be blamed on this organism. In view of the circumstances and the general condition of the river at this point, it seems clear that some relation exists between the low D.O. values, which presumably have been causing fish deaths, and local industrial plant operations. The details of this must, of course, be investigated in order to determine exactly what is responsible for this slaughter. The most likely presumption is that some carbohydrate industrial effluent, under high temperature and low water conditions, furnishes the substrate for heavy bacterial growth with the resultant exhaustion of the oxygen supply.

Lower Third

Wabash River

The Wabash River rises in Mercer County, Ohio, and flows across Indiana to Covington, before turning south to join the Ohio River about ten miles above Shawneetown, Illinois. This basin covers most of the state of Indiana and a large section of Illinois. The total area of the basin is 33,100 square miles, 320 square miles or 1 per cent of which is in Ohio, 24,220 square miles or 73 per cent in Indiana, and 8,560 square miles or 26 per cent in Illinois. Included in this area are the tributary basins of the White River, the Embarrass River, the Vermilion and Little Vermilion Rivers, the Little Wabash, Eel, Mississinewa, Patoka and Tippecanoe Rivers. The length of the Wabash River is about 475 miles. The average slope below Lafayette (mile 311.7) is about 0.6 feet per mile.

The population of the basin in 1940 was 2,508,598, divided about equally between rural and urban dwellers. Indianapolis, situated on the White River, with a population of 386,972, is the largest city in the basin.

The leading industries are manufacture of steel, paper, textiles, leather, machinery and transportation equipment. A small amount of coal is strip mined in the western part of the basin. A large portion of the building limestone of the country is produced around Bloomington. Oil production in eastern Illinois, near New Harmony, Indiana, is increasing.

The plankton samples for the Wabash River were taken during August, September and October, 1940, with the majority of the samples taken in September. Rain occurred in the Indiana region at the end of August, and September 10 and 25. The September rains were generally light and did not appreciably affect stream conditions, except for the samples taken during the rain. Because of the time-spread of the samples, it is not possible to present the results of this study in a single continuous curve. It will be necessary, therefore, to discuss the findings with some regard to the time sequence.

One of the characteristic organisms of the Wabash River and also of the White River, is a Stephanodiscus which appears frequently and in large numbers. The combination of size and number exerts a great effect upon the planktor volume figures. In August this organism was found localized in the upper portion of the river, above Logansport (mile 355). Later in the month numbers were also found at Pittsburg (mile 331) and Hillsdale (mile 238). Rains occurred throughout the watershed the last days of August and may have been instrumental in the new distribution found in the first few days of September. At this latter time the diatom was almost totally absent above Logansport, but was found in numbers from Logansport to the vicinity of Lafayette. Toward the end of September and early in October, its population center above Logansport was again established, though the organism could also be found at Georgetown (mile 347).

In addition to this factor in the volume values, there must be noted the usual seasonal fluctuations of the relative numbers and distribution of the plankton (Table 14). It should be borne in mind that the Wabash River has no dams to cause a pooled condition of the river during the summer low water period. The flow is, therefore, somewhat swifter than in a dammed stream. In general, as the summer season advances and the river level drops, it will be found that the plankton volume drops and the proportion of Class II organisms increases immediately below the source of pollution. Examples of this are found in the region below Terre Haute, Perrysville, Logansport, Peru, and other major points of pollution. This may be ascribed to the sequence of the processes of decomposition of organic pollutants outlined above.

Conversely, at points further downstream, below these same sources of pollution, the proportion of Class II organisms may decrease, due to the upstream completion of the disintegration process under higher temperatures and reduced stream flows.

At the end of September, and the beginning of October, when low temperatures start to appear in this basin, the plankton is found to decrease sharply and the Class II organisms and certain of the intermediate group become diminished in number, or are totally absent. This parallels the findings in other basins.

Judged by the plankton volumes, certain of the towns along the upper river are important sources of pollution. This is readily checked by casual visual survey of the regions involved. Peru, for example, for a short distance below the outlet of its sewage treatment plant, produces a heavy algal growth along the river, which in this region is rather shallow. This characteristic of the river bed becomes further accentuated nearer Logansport. Above Logansport, the stream appears rather clean. Commencing at the outfall of the upper sewers, there is found a region of intense pollution, which exists downstream for a considerable distance. During the summer season the stream at this point is shallow and rocky, so that considerable pooling results and numerous narrow channels are formed. The bottoms and sides of the channels are covered with a growth of attached Protozoa and other organisms common to extremely polluted regions. Further downstream, the growth of algae is very heavy and the various odors are unmistakable. It is probable that under conditions of high stream flow the sewage introduced at this point is carried for a considerable distance downstream.

The peak of the plankton, due to Logansport pollution probably, occurs in the region of Delphi, some twenty-odd miles downstream. From Delphi the volume of organisms drops off until the influence of the Lafayette effluent is felt in the vicinity of Independence (mile 294). At times of high water the peak may occur further downstream.

Terre Haute (mile 215) is a source of heavy pollution to the Wabash River. In addition to the untreated domestic waste of its residents, a number of commercial plants along the stream introduce their wastes into the river. At this point the current is fairly swift so that the waste materials are distributed for a considerable distance downstream. Nevertheless, the combination of sewage and industrial wastes introduced at this point results in a D.O. of less than 4 p.p.m. and high coliform organism and B.O.D. values for some 35 miles downstream. Due to the swift current and distribution of the pollution over a considerable length of the river, the fertilization effect on the plankton is not localized to the point of producing a prominent peak such as is found under certain other conditions. Such peak as there is seems to occur far downstream at Meron Ferry (mile 165). Both magnitude and location of the peak are variable.

From Meron Ferry downstream the plankton volume gradually falls off. There is a slight peak at Patton (mile 102), and from a point below Mt. Carmel (mile 95, below the mouths of the White and Patoka Rivers) there is a slight rise in the plankton volume as the mouth of the river is approached. This may be due to a combination of additional pollution from towns along the river and the influence of the dams on the Ohio River in slowing up the flow at the mouth of the Wabash. This allows time for the organic material to decompose to available food and for the plankton organisms to multiply.

The Wabash River on the whole has a good fish fauna. Certain of its tributaries have the reputation of being excellent game fish streams. Among these may be included the Mississinewa, Tippecanoe and Eel Rivers. Wildcat Creek, which enters above Delphi, is also rich in game fish. Above Peru, the Wabash River contained smallmouth bass, crappies, sunfish, mooneyes and shiners. The crayfish found in this location were clean and brightly colored, similar to those in the Mississinewa River, which enters close by. Below the Peru sewage plant, where the water supported a heavy growth of algae, gar pike, common suckers, several smallmouth bass, smallmouth buffalo, mooneyes, sunfish and shiners were present. Above Logansport, in addition to gar pike, common suckers and smallmouth bass, a number of channel catfish were present. Sunfish and shiners were also abundant. Large fish were seen breaking water further out in the stream. Many snails were present in this region.

Below Logansport, in obviously foul water vith heavy sludge and marginal algal growth, fish were relatively scarce; several suckers, sunfish and shiners constituted the catch. At Delphi, fish were plentiful and varied. Smallmouth and white bass were caught, and common and redhorse suckers were large. Mooneyes were also of large size, both yellow and channel catfish were found, and long-eared sunfish, shiners and darters all seemed well-fed.

Above Lafayette, smallmouth bass seemed common, while sunfish, shiners and darters were quite plentiful, in spite of poor seining conditions. Below Lafayette, bass were absent but gar pike, channel catfish, mudcats, shiners, darters and sunfish were plentiful. The marginal algae were very abundant.

The river bottom consisted of shifting sand. At Covington, the fish species again became numerous and varied. White bass and large- and smallmouth bass were present, as well as mudcats and bullheads, quillback suckers, sunfish, shiners and gar pike. The bottom of the river was muddy in this region.

At Montezuma several white bass were taken, while both mud and channel catfish were very numerous, but small. Sunfish and minnows were plentiful, and quillback suckers were also caught. Natives report buffalo and suckers present. A short distance above Terre Haute the seine captured largemouth bass, common suckers, channel catfish, mooneyes and shiners. Quillback suckers were extremely numerous at this point. White bass were reported to be present.

In contrast to upstream conditions, below Terre Haute, where the stream was narrow and swift, with a clean, rocky bottom, no fish at all were taken and only two sick crayfish were found. The water was noticeably bad; garbage, algae, paper, fiber mill wastes and other debris could be seen floating in the stream.

Ten miles below Terre Haute natives reported fish to be absent; confirmatory seining was not attempted. The D.O. at this point was still below 4 p.p.m. At Meron Ferry, quillback suckers were very numerous, with sunfish, mooneyes and shiners also present. A recently dead sturgeon was found floating, and the remains of buffalo and crappies were found on the shore. Local fishermen were seen with catches of black bullheads. The natives report that bass were once plentiful at this point but are now absent.

Below Vincennes, sunfish and shiners were very abundant with an occasional small mudcat and darter. At this point there was considerable growth of algae along the shore and on the bottom of the stream. At St.Francisville, numbers of quillback suckers, shiners, chubs and some mooneyes were again collected. There was a very noticeable tendency on the part of the quillback suckers to restrict themselves to that portion of the bottom covered with algae and to be almost totally absent from the uncovered area.

Below Mt.Carmel and the mouths of the tributaries at that point, fish were varied. Large- and smallmouth black bass, sunfish, channel and mud catfish, quillback suckers and shiners were caught, as well as gar pike. Live mussels were seen, but there were no crayfish. The bottom was sandy.

At Grayville, Illinois, (mile 61), largemouth (Kentucky?) bass were plentiful, and white bass were extremely numerous. Shiners, sheepshead, quillback suckers, mooneyes, gar pike and channel catfish were found. Commercial fishermen showed large buffalo and quillback suckers, channel cats and eels. They claimed that carp and other types of fish were also present. Below New Harmony, channel catfish, largemouth bass and white bass were noted, but the principal fish present were sheepshead, quillback suckers and shiners.

Upper Tributaries - The Mississinewa River, which enters the Wabash 375 miles above its mouth and a short distance above Peru, was quite clean and contained less than 0.5 M.p.p.m. plankton. The Eel River enters the Wabash 354 miles above its mouth, at Logansport. This is considered to be a clean stream and is used for the townwater supply. At the sampling point near the intake of the city water supply, over 11 M.p.p.m. of plankton were found, consisting mainly of the diatom, Stephanodiscus. However, there were close to 0.2 M.p.p.m. of Class II organisms. Observations seemed to indicate that this was a favorite spot for horse-washing, as these animals were led into the stream and cleaned at this spot.

Wildcat Creek, entering the Wabash River at mile 317 near Delphi, contained over 2.5 M.p.p.m. of plankton, principally Intermediate forms. Many small- and largemouth bass were found here. Common, quillback and hogmolly suckers were caught. Sunfish, crappies, bluegills, mudcats, shiners and darters were plentiful. Large gar pike and walleyed pike were reported present by local residents.

Tippecanoe River (mile 322). The water of the Tippecanoe River is very clear. The river itself has a larger bottom growth of the higher aquatic plants than was usual in the Wabash watershed. Samples were taken in the river, and the two lakes which form a part of it, about September 7. Plankton was found to be less than 0.7 M.p.p.m. at all stations, although ten days earlier it had been as high as 5 M.p.p.m. at one of the lakes and 1.8 M.p.p.m. at the lowest sampling point. A certain number of Class II organisms were present in the upper reaches of the river and in the lakes. At Springboro, above the mouth of the stream, these were absent, although a few filaments of Sphaerotilus were found. The number of Class I organisms was somewhat higher at this point.

At Springboro, a number of smallmouth bass, hogmollies, shiners and darters were found. Larger specimens of these species, as well as common suckers, could be observed in the clear water from the bridge over the stream. The river is apparently a popular fishing stream and the lakes are widely used as summer resorts.

Vermilion River (mile 257) - The Vermilion River was studied in the region of Danville, Illinois, not far above its mouth. Above Danville stream conditions were fairly good. The D.O. was approximately 9 p.p.m. and the total plankton less than 1.5 M.p.p.m.

Following the stream through the town reveals a drop in dissolved oxygen and an increase in the algal growth. Below town, about one hundred yards above the entrance of the sewage plant effluent, the D.O. was 3.5 p.p.m. and a few sunfish, minnows and small black bass were noted. These were not in prime condition. Floating masses of blue-green algae were seen and the total plankton volume was about 5 M.p.p.m., of which about 3.25 M.p.p.m. consisted of Class II organisms.

About one mile below the sewage plant the D.O. was 1.87 to 2.05 M.p.p.m., and the total plankton varied between 6.5 and 9 M.p.p.m. on successive days. Class II organisms composed over two-thirds of the plankton. The water was obviously polluted and there was considerable sludge on the bottom. Several sunfish and two small German carp were caught, even though the D.O. value was below 2 p.p.m. About five miles downstream, conditions improved somewhat, the D.O. rising to about 5.5 p.p.m. Fish were numerous. Many largemouth bass, a small number of smallmouth bass, sunfish, yellow catfish, spotted darters, log-perch, quillback and common suckers, shiners and carp were caught. However, a large number of the fish were sickly, abnormal or parasitized. The bottom was still noticeably muddy. The total plankton had dropped to 3 M.p.p.m. at this point and the volume of Class II organisms was about 0.5 M.p.p.m.

At the time of sampling, the plant effluent was approximately 1/28 of the total stream flow.

Embarrass River (mile 122) - The Embarrass River, above Lawrenceville, Illinois, in the middle of September, 1940, had a plankton population of 5.9 M.p.p.m., due to a large number of the diatom, Pleurosigma. Some Class II organisms were present. Two weeks earlier the Pleurosigma and Class II organisms were both much more abundant. Several miles below Lawrenceville, at Billet, the volume of Class II organisms increased to 0.8 M.p.p.m. and the total plankton was 0.9 M.p.p.m. Above Lawrenceville, largemouth bass were extremely numerous and many quillback suckers were caught. There were some minnows, long-eared sunfish and gar pike. A carp weighing 7.5 pounds was also caught. The stream was not very wide at this point, but there were apparently some deep holes. Dissolved oxygen was 8.7 p.p.m. At the sampling point below Lawrenceville, oxygen was close to 9 p.p.m., but no fish or crayfish of any kind could be found. There was a scum of oil covering a portion of the water, and algae were floating and on the bottom. The bottom itself was an oily mud. No insects could be seen, and the water was fairly clear.

Little Wabash River (mile 15) - The rate of flow was very low in the Little Wabash River (late September). At Carmi, Illinois, the water was quite stagnant, with a heavy growth of algae covering the surface. The D.O. was high and approximated 12 p.p.m. The plankton found consisted mostly of Class I organisms.

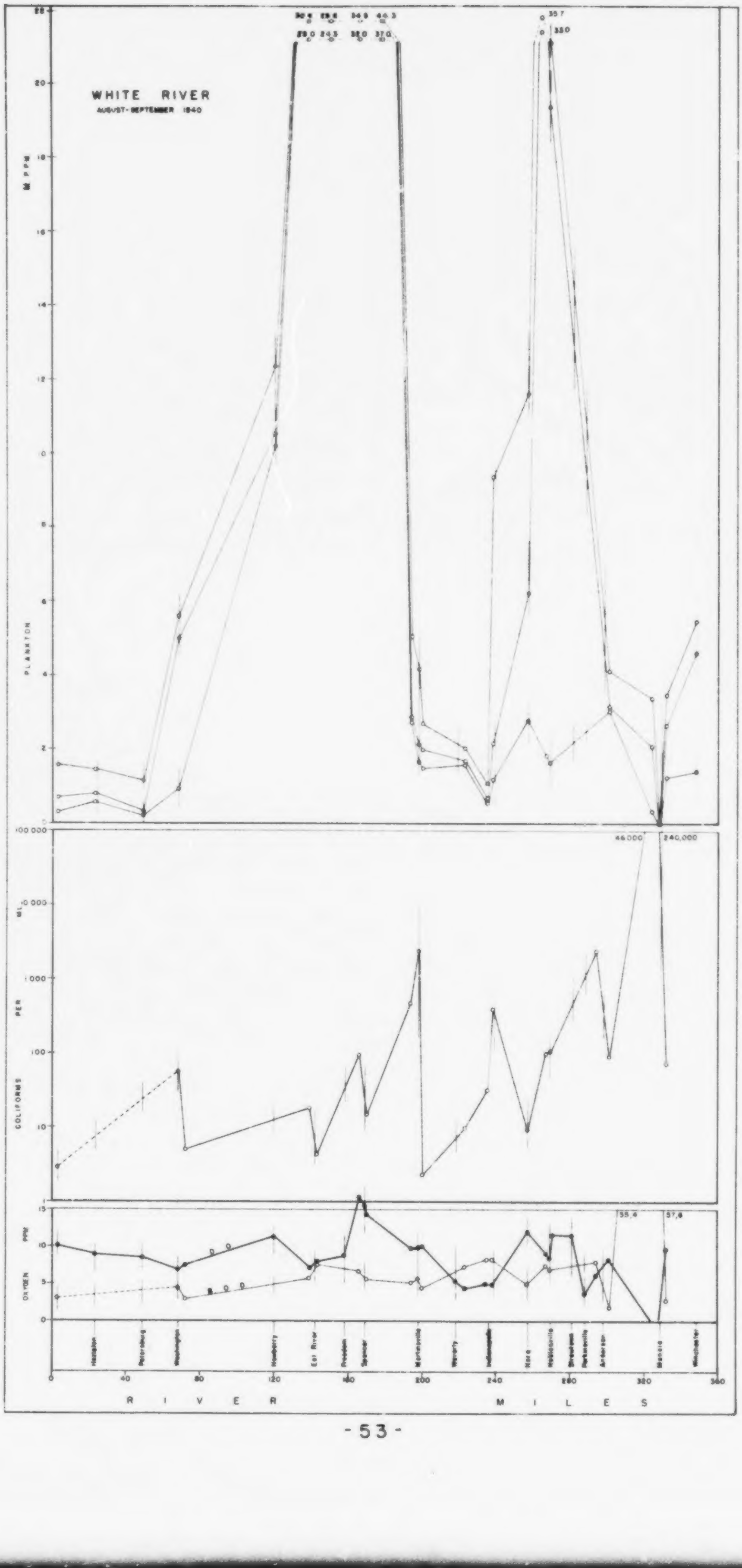
Below Emma, Illinois, deep, quiet pools occur, in which the water was quite stagnant and green. Fish were occasionally seen to break water. The plankton here was approximately 6 M.p.p.m., with over twenty per cent of this being composed of Class II organisms.

White River (mile 96) - The majority of samples from the White River were taken in the latter half of September. Three or four samples were taken in the third week of August. Samples from a given region were taken at the same period so that consecutive points in the region of a source of pollution are comparable.

As the studies of other rivers have shown, the month of September is one of stable conditions, during which light rains exert little, if any, influence upon the stream plankton. For this reason and because of the general agreement between the values at different points, Figure 12 may be taken as representative of the September conditions on this stream.

The White River is subject to heavy pollution for almost its entire course (Table 14). Our observations started at Winchester (mile 338) and Muncie (mile 309) where samples were taken in August. The pollution immediately below Muncie, as indicated by the B.O.D. and coliform organism values, is so intense that the plankton population is almost entirely destroyed. It is possible that some ciliates exist under these conditions, that, for various reasons, did not show up in the plankton samples. The recovery below Muncie is rapid but the plankton volume reaches its peak in the region above Noblesville (mile 265) where a tremendous growth of Class II organisms was found. A large part of this growth consisted of

FIG. 12


WHITE RIVER
AUGUST-SEPTEMBER 1940
PLANKTON M PPM
30.4
25.6
34.5
40.3
25.0
24.5
35.0
37.0
35.7
35.0
22
20
18
16
14
12
10
8
6
4
2
COLIFORMS PER ML
100,000
10,000
1,000
100
10
46,000
240,000
OXYGEN PPM
15
10
5
0
35.4
37.8
Hazleton
Petersburg
Washington
Newberry
Eel River
Freedom
Spencer
Martinsville
Waverly
Indianapolis
Nora
Noblesville
Strawtown
Perkinsville
Anderson
Muncie
Winchester
0
40
80
120
160
200
240
280
320
360
R I V E R M I L E S

Euglena, but Vorticella and other forms contributed a considerable volume. Anderson (mile 297) undoubtedly contributed a portion of the pollution responsible for this burst of plankton, but it seems possible that the height of the peak is related to the heavy organic load introduced at Muncie. The plankton volume fell below Noblesville and by the time Nora was reached, a few miles above the city of Indianapolis, the total volume, and especially that of the Class II organisms, had decreased greatly. In passing through the city of Indianapolis, the plankton concentration of the White River was severely reduced. This may partly be due to the number of tributaries which enter the White River in this region, to the large portion of the water which passes through the city waterworks during low water, and possibly to specific pollution factors.

The plankton recovers slowly below Indianapolis. This continues until Martinsville is reached. Below Martinsville (mile 194), conditions seem to be favorable for the proliferation in great numbers of large species of diatoms, especially Stephanodiscus and Synedra. This diatom population continues on past the mouth of the Eel River to Newberry, where, possibly due to the diluting effect of this tributary, the total volume falls off. At Washington (mile 62), most of the Stephanodiscus have vanished and Class II organisms appear under the influence of fresh pollution at this location. From this point downstream the total volume of plankton falls off to approximately 1.5 M.p.p.m. above the mouth.

At Perkinsville, several miles below Anderson, bass, buffalo, shiners and a black bullhead were caught. The water was obviously dirty at this point, with algae covering the stream bottom. At Strawtown, several miles below, the appearance of the stream was much better, pollution not being obvious. At Noblesville, many shiners, some sunfish and some darters comprised the catch. Stream conditions appeared good. Local fishermen reported that bass, buffalo, carp, catfish, crappies, bluegills and other fish are caught in season.

At Nora, smallmouth bass and some shiners were caught under difficult seining conditions. Some large unidentified fish escaped. It is assumed that under better seining conditions the catch would have been considerably greater.

Below Indianapolis, above the last waste outfall, some sunfish and a largemouth buffalo were caught. The bottom was gravel, with a strong current, but considerable blue-green algae were visible. Fishermen reported that only carp and catfish were caught here. Fish, presumably mooneyes, were seen breaking water occasionally at the mouth of the outfall. A local resident told of many fish deaths a distance above the sampling point a week or two earlier. The period of the slaughter coincides with that of the hottest weather of the month. The above story is borne out by the extremely numerous skeletons and weathered corpses of large fish along the shore.

At Martinsville, large common and quillback suckers, hogmollies, sunfish and numerous minnows are found. One largemouth black bass was caught. The river bottom consisted of black oily mud with a strong odor, and algal growth was plentiful. All the fish caught showed a tendency to the dark phase, which in the minnows was expressed so strongly that the dorsal color was bluish-black.

At Spencer, the bottom was muddy but had a sandy underlayer. There was a green covering on the flat rocks in the stream. Common and quillback suckers, spotted suckers, sunfish, channel catfish, shiners and chubs were caught and largemouth bass were very plentiful. It is possible that the fish were more active due to the rain which fell the previous night and the early part of the day.

At Newberry, largemouth bass were caught, as were some sunfish, shiners and darters. Channel catfish were numerous. There was no mud on the bottom, possibly due to the marked current, but algae were visible.

The Eel River, whose mouth lies above this point (plankton 0.6 M.p.p.m., D.O. 8.5 p.p.m.), had a number of largemouth bass, possibly some Kentucky bass and shiners, darters and some minnows. Below the sewer at Washington, the bottom was sandy but there was a slight odor to the water. Seining conditions were not good. Gar pike, largemouth black bass, quillback suckers and shiners were caught, while channel catfish and darters were also plentiful. Above Petersburg, the White River is joined by its East Fork, which appears to be a good stream (plankton 0.5 M.p.p.m., D.O. 7.75 p.p.m.). Conditions here were not very favorable for seining, but largemouth bass, channel catfish, quillback suckers, shiners and sunfish were caught. Blue herring were found in large numbers at this point. Below Petersburg, considerable mud was encountered in the White River. Channel catfish were plentiful, with mudcat also present. Small bass were numerous, many quillback suckers were found, and sheepshead, shiners, sunfish and several types of minnows were caught.

Below Hazleton, stream conditions looked good. Several largemouth bass and some gar pike were caught, sheepshead, mooneyes, quillback suckers and shiners were plentiful. No catfish were obtained, even after extensive seining. The bottom was sandy.

Above the mouth of the White River, largemouth black bass, small mudcat, sunfish and minnows were caught under unfavorable conditions. Buffalo, carp and gars were reported to be plentiful, bass less numerous, and it was said that an occasional sturgeon was caught. This information was derived from the proprietor of a local fishing camp. Some large, slimy fish (gar or sturgeon) tore a hole through the net and escaped.

Patoka River (mile 95) - The Patoka River was visited during the middle of September. The first samples were taken a short distance above the mouth. When first observed from the bridge, the water presented a greenish-blue appearance, due to some milky suspended material. Otherwise the water was very clear.

Several large carp and redhorse suckers were seen traveling downstream, while black catfish, a ten-inch bass, an eel and other large fish were seen moving slowly in various directions. No minnows were observed. The fish were making efforts to escape from the pool in which they were found, but were apparently unable to cross the shallows at either end. The fish were relatively sluggish and it was possible to capture a 23-inch dogfish (Amia calva) in a dip net. Although the condition of the water was attributed locally to the waterworks at Princeton, the waterworks records showed that the stream often was very acid due to mine drainage and pumpage. In addition, there was often a heavy salt load from oil well pollution, as well as high "hardness" values. A wave of acid water had passed downstream at about the time observations were made. One week later, the pH at the waterworks dam was 6.8. No fish could be found by seining. Plankton was 0.33 M.p.p.m. above the dam and 2.5 M.p.p.m. below. The waterworks operator reported that sludge was flushed into the stream at intervals of six months or longer. No records were obtained of the effects of this sludge upon the aquatic life of the stream.

Saline River

In early October the Saline River, a minor Ohio River tributary in Illinois, was extremely low and discontinuous, with almost no current. Some regions resembled stagnant sewers. Near the mouth the stream is situated in the Shawnee

National Forest. At flood season, this locality is a deep backwater of the Ohio River. The bottom consists largely of rock ridges, with deep pools between riffles.

Seining conditions were poor, but largemouth bass, logperch, crappies and small sunfish were caught. Minnows were seen in the shallows, and larger fish were breaking water in the middle of the stream. A ranger reported a considerable variety of fish, such as catfish, sheepshead, gar pike, etc. Plankton was plentiful, approaching 1.5 M.p.p.m. (Table 15).

Tradewater River

The Tradewater River is a narrow, deep Kentucky stream. At the time of observations in October, practically no water was flowing. Fish caught near Sturgis, Ky., consisted of common suckers, Kentucky bass, bluegills, sunfish, quillback suckers, sheepshead and some shiners. The water appeared green and dirty but the total plankton volume was only 0.17 M.p.p.m., almost half of this consisting of Class II organisms (Table 15).

Another sample taken near Providence, Ky., showed crappies, quillback suckers, mooneyes and some small sunfish and shiners. The water here was shallow and dirty and was used as a watering place for live stock. It is probable that this portion of the river was not connected with the lower river at this season.

Green River

The Green River rises in Casey County, Ky., and flows in a general westerly direction to join the Ohio River above Evansville, Ind. The length is 370 miles and the average slope below Mammoth Cave (mile 198) is about 0.5 feet per mile. It drains an area of 9,220 square miles.

The population of the Green River Basin in 1940 was 440,000, of which only about 10 per cent were found in incorporated towns, the largest of which was Bowling Green (pop. 14,585). The principal resources are coal, timber, asphalt, oil and gas. The principal industry is agriculture. Six locks and dams produce slack water up to Mammoth Cave, and one lock and dam each on the Barren and Rough Rivers produce slack water as far as Bowling Green and Hartford, respectively.

The Green River, for a large part of its course, is a wide deep stream and it was, therefore, difficult to estimate the fish population. The trap net was used on a number of occasions and at times it was possible to seine immediately below the dams. Even at these locations, however, conditions were usually unfavorable for fishing. Bait fishermen, however, were successful at a number of locations. Fishing conditions were better in the numerous tributaries of the Green River, and results from these must be used to a large extent.

Plankton, on the whole, is extremely low all along the Green River. For the most part, the total volume is less than 0.2 M.p.p.m. (Table 15), although a sample taken at Dam 4 showed over 1 M.p.p.m. It should be pointed out that this dam lies below the mouth of the Barren River on which is situated the city of Bowling Green. Seining was possible at points from Dam 6 at Brownsville up to about Eunice, Ky. In this region could be found smallmouth and Kentucky bass, common, redhorse and hogmolly suckers, log-perch, darters, shiners and an occasional blue herring. Bass caught at Brownsville were a very translucent, pale color and may have been sick. At Munfordville, which is just within the limestone cave area, fishermen reported catches of large bass, pike and muskellunge. It is to be noted that the reserve alkalinity in this region of the stream (Munfordville to Brownsville and below) is approximately double that found higher up the stream. This is, of course, to be ascribed to the limestone drainage.

Trap net fishing between Brownsville and the mouth of the river was on the whole unsuccessful, due to the nature of the stream. Kentucky bass and sunfish constituted the catch. Mooneyes were often observed breaking water. Fishermen at Dams 3 and 4 had catches of bass and walleyed pike. At Livermore, at the mouth of the Rough River, natives report catfish as the exclusive catch. It was possible to seine the Green River at Rumsey. Bass, sunfish, channel catfish and shiners were collected. In addition to bass and minnows, blue herring were found at Spottsville, near the mouth of the river.

The tributaries of the Green River showed, on the whole, higher plankton and better fishing than the main stream. However, at this time (October), these streams were very low.

Pond River, into which the sewage of Madisonville is emptied, gave the only catches of small pike; sunfish, bullheads and shiners were also present. In addition to the Madisonville pollution, there were local pollutions at some of the sampling points, due to their use as water-holes and as pools for domestic fowl. At the mouth of the Pond River, largemouth black bass and Kentucky bass, possibly coming from the Green River, were captured. Natives report fishing in the Pond River to be basically good, but frequent pollution by mine waters kills the fish. Plankton in the stream was uniformly high, approximating 1 M.p.p.m. Near the mouth, the Pond River receives the drainage of Cypress Creek which is highly polluted by mine wastes. At the time of sampling the pH was 3.2. Plankton was 0.26 M.p.p.m., almost half of which consisted of the diatom, Navicula.

The Rough River for the most part showed low plankton and a scarcity of fish. At Falls of Rough, where the plankton was 0.3 M.p.p.m. and considerably higher than that found at other points in the stream, sunfish were fairly plentiful, as were shiners and chubs. At Hartford, approximately 20 miles from the mouth of the river, fish were very scarce. Two pavement-toothed redhorse suckers and two shiners constituted the total catch. Acid mine drainage is a source of pollution. The higher points on the stream yielded hogmollies, darters, chubs and shiners.

The Nolin River is, for most of its course, a small stream, along which are situated several towns. At several points plankton is higher than in the Green River. Catches did not contain large numbers of fish, but among them were smallmouth bass, darters, sculpin, sunfish and shiners. The Nolin River runs through the limestone area and enters the Green River near Mammoth Cave.

The Barren River has a navigation dam below Bowling Green, but above that city it is a fairly small stream. The upper reaches consist of alternating shallow, narrow riffles, and large, deep pools. Fishing conditions were not good. Plankton above Bowling Green was less than 0.1 M.p.p.m., although it was somewhat higher in the region of the dam. Shiners, darters, hogmolly and common suckers and sunfish constituted the fish catch in the upper portions of the stream. Natives report a few bass present, especially in the spring. Below Bowling Green and Dam 1, log-perch, darters, bluegills, sunfish, common and redhorse suckers and many small mooneyes were caught. Shiners were seen in the water. Pike and bass fishing were normally good, but at the time of our visit, dynamiting and construction work which was going on nearby probably disturbed the fish.

The Mud River was sampled near its mouth, and yielded common and quillback suckers, crappies, sunfish, shiners, darters and some unknown striped minnows. At this point the stream was narrow and deep with a mud and humus bottom. At Lewisburg, the oxygen was 2.6 p.p.m. The water was black and many dead leaves were present. One shiner and one darter were the sole catch. It is possible that the dead leaves may have been responsible for the color of the water and the low D.O. values. Reserve alkalinity in this vicinity was much higher than at the mouth.

Cumberland River

The Cumberland River is formed by the junction of Poor and Clover Forks in the southeastern part of Kentucky. It flows southwest into Tennessee, then northwest into Kentucky and finally empties into the Ohio River at Smithland, Ky. Its length is about 687 miles. The average slope below Burnside, Ky., (mile 516) is about 0.6 feet per mile. The Cumberland drains an area of roughly 18,000 square miles. The river has been canalized for 331 miles by the construction of fourteen locks and dams.

The population of the basin in 1940 was 1,129,000, of which 277,724 were in communities of over 2,500. Over half of these, or 167,402, lived in the city of Nashville.

The principal resources of this area are coal, zinc, iron, limestone and oil. The principal industries are agriculture, products of cement, rayon textiles and chemicals.

Observations were made on the Cumberland River during the months of October and November, 1940. Samples were taken from Dam 8 (mile 317) in Tennessee, to Dam F in Kentucky, approximately 45 miles from the mouth of the river. Heavy rains occurred during the survey period, but some observations, both before and after the rain, indicated that no important variation was introduced by this factor. Likewise, an unseasonable cold spell occurred towards the end of the period of observation, which brought the water temperature in some cases down to 10° C. Both of these conditions, the rain and the drop in temperature, may affect the absolute values of the samples from Dams 4 to 8 and from Dams C to F. The center region of the river was studied prior to the onset of the rains and, therefore, may be considered fairly representative of the late summer conditions. The probable effect on the plankton volumes at the two ends of the observation range is not more than 100 per cent, which does not affect the general plankton picture of the stream (Figure 13 and Table 16).

From Dam 8 to Dam 3 the plankton level was quite low. The slight rise in the values at Dam 4 may perhaps be attributed to the discharges from Gallatin and Lebanon, which are situated

Fig. 13

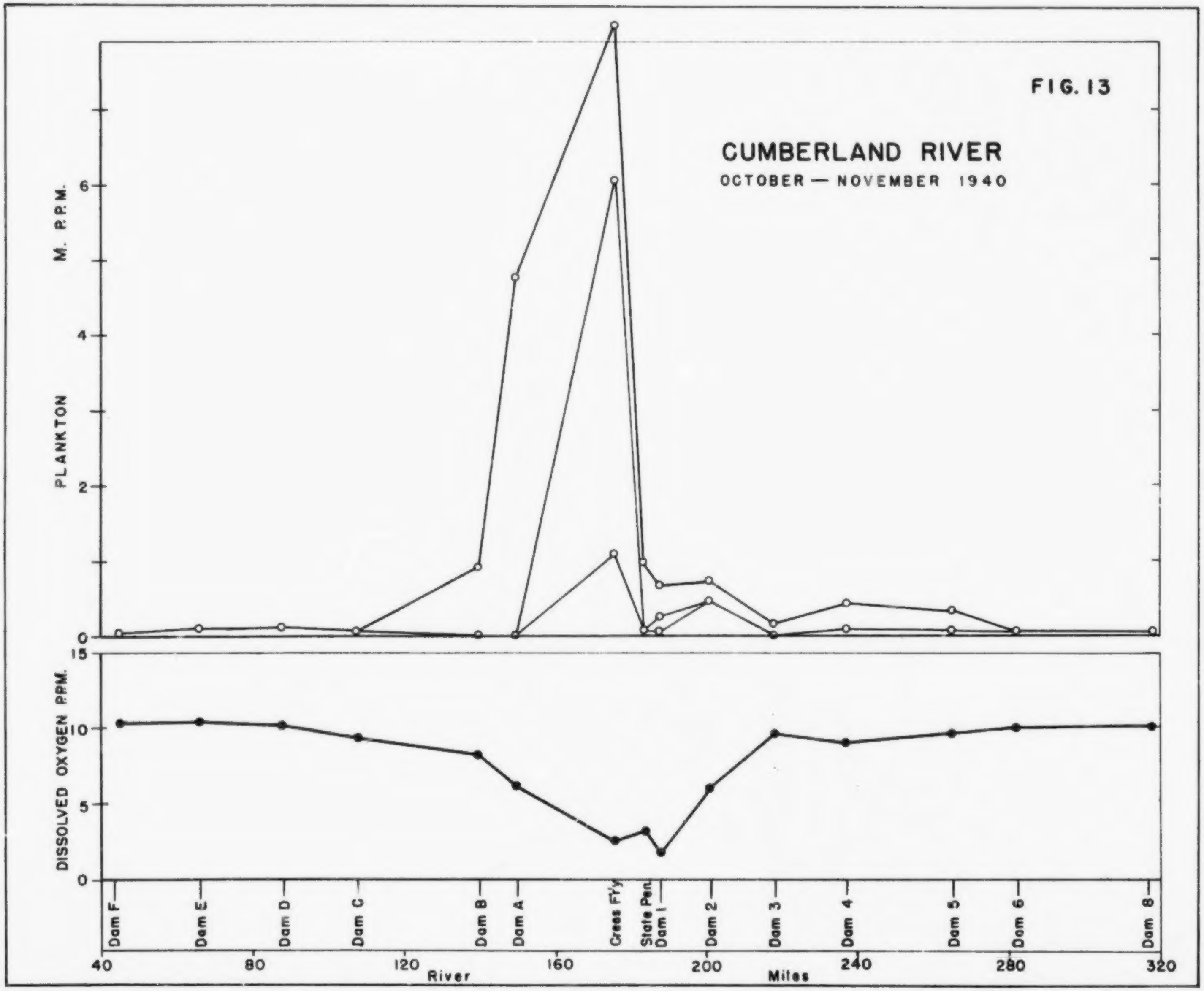


FIG. 13

CUMBERLAND RIVER
OCTOBER — NOVEMBER 1940

on small side creeks. From Dam 3 to Dam A is found a relatively concentrated human population. Between Dams 2 and 3 is located a rayon plant, with a grouping of small towns in the vicinity. The city of Nashville, with its large concentrated population, suburbs and large number of industries, is located just above Dam 1.

It is seen that the location of the population is indicated in both the plankton and dissolved oxygen curves. The plankton commences to rise above Dam 2 and reaches a peak some miles below Nashville. This peak, due largely to Class II organisms, falls off slowly down the river. The last of this plankton hump is found somewhere below Dam B. The State Penitentiary, several miles below Nashville, contributes a fair amount of waste. Between this location and the next sampling point, Crees Ferry, is located a paper mill, which causes a very noticeable blackening of the stream below its location.

The oxygen curve shows a distinct drop between Dams 2 and 3 and reaches a minimum at Dam 1 immediately below Nashville. Recovery is slow, and is not complete before Dam B, approximately 48 miles downstream.

The Cumberland River shows in almost diagrammatic form the effect of an isolated source of heavy pollution upon a relatively clean stream. It is possible that if there were no navigation dams, the effect of Nashville pollution would be evident further downstream.

The State Department of Conservation plants fish rather extensively throughout portions of the Cumberland Basin in Tennessee. This may account for some of the specimens found in side streams and, to a certain extent, in the Cumberland River itself. It is evident from the catches, however, that there is sufficient nutritive material to enable the fish to grow to good size.

In fishing the Cumberland River, it was the practice to set the trap net in the current below various dams. Shallower tributaries were seined. At Dam 8 an overnight catch consisted of two crappies; at Dam 6, crappies to ten inches in length, Kentucky smallmouth bass to nine inches, bluegills and sunfish. Other fishermen caught sheepshead, and redhorse suckers. At Dam 5 fish were more varied, consisting of crappies, darters, log-perch, shad, and numerous shiners, chubs and quillback suckers. Bass were undoubtedly present, although none were caught.

Kentucky bass were found at Dams 3 and 4, with shad seen in fair numbers. These last fish were eating the algae from the dam and the lock walls. Dam 2 also yielded Kentucky bass and sunfish. Dam 1 was visited twice, once immediately before and once immediately after a rain. Water conditions were very bad at the time of the first visit, the D.O. being less than 2 p.p.m. above the dam. Crayfish were found along the bank, approximately half of them being completely out of water, apparently to avoid the asphyxiating conditions in the stream. These crayfish were often very heavily covered with a white growth, presumably fungus. In the lock itself, water, which had been isolated from the river overnight, contained less than 0.7 p.p.m. of oxygen. Fish were numerous in this water and swam either at the top or close to the top, seeming to prefer the region of the lock walls where algae were growing. They came to the top apparently to gulp air. Some of these fish could be captured by means of a dip net. Among them could be seen catfish and gars of large size, shad, sunfish, minnows and bass. About four days later, following a rain, the oxygen was approximately 6 p.p.m. and crayfish were no longer visible along the banks.

Sheepshead, numerous Kentucky bass and crappies were found at Dam A, and Dam B yielded Kentucky bass. The fish caught at this Dam showed very noticeable tail and palate infections. After this find, such infections were watched for in all cases and found to be fairly common, although not quite so numerous, both above and below this point. The State Conservation Department informed us that this was an infection by fungus with which was associated a species of Hydra.

At Dam C the water was somewhat muddy, due to the discharge of the Red River, upstream from that point. The net catch consisted of smallmouth buffalo, channel and mud catfish and a number of sheepshead.

At Dam D the catch was Kentucky bass, while at Dam E a white bass and a large number of channel catfish were caught. Dam F yielded Kentucky bass and crappies in the fyke net, while shiners and shad were caught in the lock with a dip net. A large white bass was also seen swimming in the lock water. It may be noted that at this dam, which is the site of the Western State Penitentiary (Eddyville), with a population approaching 2,000, the bass were the fattest found on the river.

Stone's River, which enters the Cumberland above Nashville, showed a heavy algal growth. Oxygen was good and a variety of fish were found. The species captured were sunfish, bluegills, Kentucky bass, mud catfish, shiners, darters, smallmouth black bass, log-perch and chubs. Frogs, tadpoles and salamanders were caught and the crayfish found at this point were very clean and brightly colored. The plankton found was of approximately the same level as the catch at Dam 1. Seining conditions at the Harpeth River were not good. Two kinds of minnows were caught. It is reported that a chemical plant empties its wastes into this river. The electrical conductivity of the water was not noticeably higher than that found in Stone's River, although samples were taken following a rain. The total plankton was less than 0.1 M.p.p.m.

Main Ohio River

The Ohio River is acid from Pittsburgh to mile 172 (below Pittsburgh) at Marietta, although on occasion the effects are felt as far downstream as the mouth of the Kanawha River at mile 266. The River is near neutral (pH 6.9 - 7.4) from Marietta to mile 320. From mile 320 the alkalinity increases slightly to the mouth (pH 7.4 - 8.5). The Ohio seems to be relatively stable chemically and bacteriologically, compared to its tributaries. Cincinnati and, to a lesser extent, Louisville, make their locations known by their effect on the D.O., B.O.D. and coliform count. With these exceptions, however, and that of a possible gradual increase in B.O.D. and bacterial count in passing down-river, there is relatively little chemical or bacteriological variation. This can be ascribed to the large dilution factor due to the stream size.

A large number of plankton samples was collected from the middle third of the river, from mile 316 (above the mouth of the Big Sandy) to mile 531 (Dam 29), in the interval from May 1 to December 28, 1939, (Table 17). Fewer samples were taken in the upper and lower thirds in 1940. No fish collections were made.

The plankton of the Ohio River contains fewer genera and species than that of the main tributaries. The plankton volume immediately below Pittsburgh, at the Emsworth Dam, in October, 1940, was extremely low, less than 0.1 M.p.p.m., and consisted mainly of Closteriopsis and some small green algae. The population fluctuated, with an irregular tendency to increase downstream to Marietta, Ohio, (mile 172). The low plankton volume and the limited variety of planktonts are correlated with the acidity of the upper portion of the river. During the summer period, the river in the region above Marietta may reach a pH value as low as 4.1, and is usually acid, even in the spring and early summer.

In June and July the plankton volume in the neutral portion of the upper third of the Ohio (below Marietta) was occasionally as high as 4 M.p.p.m., while in August and September the volume remained at lower levels. The most numerous forms in the June-July period were Chrysococcus, Chlamydomonas and a variety of green algae (diatoms). Closteriopsis, Chlamydomonas and Cyclotella dominated the fall plankton in this region.

In the middle third of the Ohio River, in May, 1939, a large bloom of diatoms was the striking feature of the plankton. The principal genera involved were Asterionella, Gomphonema, Nitschia and Synedra. The highest volume value of plankton found was 74.7 M.p.p.m. at Dam 37 (Cincinnati) on May 12. There were no data from above mile 405 or below mile 531 to indicate definitely whether this bloom was local, general, or was moving downstream. The data at hand suggest that there was a movement of the diatom bloom downstream. The data indicate that in general the plankton population at Dams 37, 38 and 39 (below Cincinnati) was greater than at the stations above. This may be attributed to the fertilizing effect of the waste from the Cincinnati area.

The high plankton volumes in the lower part of the river, from mile 600 to mile 730 (1940), are due largely to diatoms, principally Melosira, Synedra and Fragilaria. Asterionella becomes important in the samples near the mouth of the river below mile 800 (November).

The Ohio River seems to possess a plankton population which is characteristically different from that of its tributaries. The outstanding characteristic of the Ohio plankton is the presence of large numbers of diatoms of genera not prominent in the plankton of its tributaries. Modifying this is the acid condition in the upper portion of the river. This results in Closteriopsis, the form dominating the acid waters of the Monongahela River, extending its range down through the acid regions of the Ohio River below Pittsburgh.

The equipment on hand was not adequate to make a detailed study of the fishes of the Ohio River. Considerable fishing, however, is done with set lines by the river people, and large catches of carp and channel catfish were reported at various places along the river below Liverpool, West Virginia. Many gar pike and mooneyes were seen breaking water at Marietta, Ohio, and Ashland, Kentucky. Fishing for river chubs is a favorite sport for children along the middle third of the river, and an occasional walleyed pike is taken.

DISCUSSION

Owing to the large area of the Ohio Basin (204,000 square miles) and the short time allotted to the survey (two years), it was impossible to attempt a completely satisfactory biological study. It is realized that there are inaccuracies in the method of sampling and computation and the danger of misinterpretation due to the small number of samples taken at a given point. It is well known that the biological picture of a stream varies with the year, the season and even the time of day. While the data cannot be considered complete, the general agreement between series of samples and the support of comparative data strengthen the deductions from a given sample. The long series of samples taken at fixed points in the Ohio Basin from May through December, 1939, show the influence of seasonal and climatic factorson the plankton and, through evaluation of these influences, it has been possible to increase the significance of the interpretations of individual samples.

A study of the data presented brings out the following topics for discussion.

Organic Pollution

Pollutants which enter streams from city sewers or organic industrial plants, such as canneries, meat-packing houses and creameries, affect the aquatic life in a variety of ways. The waste may have an immediate toxic effect or, as is more often the case, the waste may induce rapid multiplication of aerobic bacteria which sharply lower the dissolved oxygen concentration, frequently to the asphyxial level for fishes, and often to depletion. This is probably the most common cause of mass death of fish in streams of the Ohio Basin (see Trautman[5]).

The lowering of the dissolved oxygen concentration, accompanied by high biochemical oxygen demand and a high count of coliform bacteria (if the pollutant is sewage) is evident for a distance, below the source of pollution, which depends upon the temperature, rate of flow, and type of stream. It may vary from a few hundred feet to several miles. Biologically, this region is dominated by Class II planktonts, and the fish are principally of the coarse varieties, such as carp and buffalo. Abundant fungi and stalked ciliates may be attached to solid surfaces.

This zone gradually blends into the next, which is characterized by a large variety and volume of photosynthetic plankton organisms and a high diurnal variation in the dissolved oxygen concentration, from supersaturation on some afternoone to very low values before dawn (see Denham[6], and Butcher, Pentelow and Woodley[7]). This marks the maximum fertilization effect of the pollution introduced upstream. In this region is usually found a large mixed fish population.

Further downstream, the high concentration of nutritive materials has been greatly reduced by the heavy upstream growth of plankton, and only the thrifty forms persist (Chrysophyceae, Cryptophyceae, and certain diatoms). This reduction in fish food has a direct effect upon the fish population, so that the game fishes are the dominant forms and the numbers of plankton feeders are reduced.

Where proper treatment is given to the wastes before they are turned into the stream, the early obnoxious stages of the natural purification processes are greatly reduced or entirely eliminated. Primary treatment plants, which remove the solid suspended materials from the wastes, result in less sludge being deposited in the stream, and in more immediate and rapid decomposition of the soluble materials. If the effluents are introduced into a stream where proper dilution occurs, conditions may never become obnoxious. If the treatment plant effluent forms a larger portion of the total stream flow, as in the Vermilion River below the Danville treatment plant, conditions may become acute for aquatic life, but the acute conditions are relieved in a comparatively short stretch of the stream, and the fertilization effect predominates.

The aim of secondary treatment of wastes is not only to remove and break down the solid components of the waste, but, by means of trickling filters or activated sludge, to allow a portion of the bacterial action to take place before the waste enters the stream, thus lowering the biochemical oxygen demand of the effluent and presenting it to the stream in a form more available for the plankton. This results in an even more marked reduction of the region of acute conditions and of the time and distance before the peak of the plankton volume is reached. Ideally, there should be no harmful effects from the effluent of a secondary treatment plant on fish life.

In practice, the results achieved by this type of treatment are dependent upon the efficacy of the plant and the total amount of waste treated. Thus, Peru (pop. 12,000), on the Wabash River, with a secondary treatment plant operating for only a few months before the time samples were taken, showed no obnoxious oxygen conditions and an immediate heavy growth of algae and plankton below the plant effluent. The stream cleared itself of even this index of pollution in a very short distance. On the other hand, Muncie (pop. 46,000), on the White River, despite extensive corrective measures, contributes a load of residual organic material that is important in relation to the size of the stream at that point, and biological conditions are affected for some distance. On the same river, but at a point where flow volume is somewhat greater, the much larger city of Indianapolis (pop. 370,000) also affects the river B.O.D., D.O. and biology, but the effect is not in proportion to that at Muncie.

It should be pointed out that the introduction of untreated industrial wastes which are not necessarily available in any form for plankton food, complicates somewhat the natural purification processes. Thus, the entrance of creosoting wastes together with untreated sewage, as in one instance, may greatly slow down the bacterial decomposition of the organic matter, and result in a greater downstream propagation of the obnoxious stages of pollution. In addition, the presence of complicating toxins may appreciably raise the minimum oxygen requirement for fishes (due to increased metabolic rate) and thus cause an oxygen level, which may be ordinarily tolerated, to become definitely lethal.

As has been noted by other workers,(8) the presence of high pollution renders the incidence of parasitizations and developmental abnormalities much higher in the fish population. Thus, in the Vermilion River, below Danville, where the fish population was definitely high, parasitized fish and deformed fish were numerous. A more striking example was found in the Big Blue River, a tributary of the White River, where the fish taken below Carthage were all extremely heavily parasitized by organisms causing black or brown spots in the skin. The parasites were found in abundance up and down the stream, which is subject to repeated pollution, but the heaviest incidence of the parasites occurred at the location mentioned.

Industrial Wastes

The industrial establishments in the Ohio River Basin, in addition to canneries, creameries and meat-packing plants, are steel mills, coal mines, paper and pulp mills, distilleries and breweries, and oil and gas refineries. The acid wastes from steel mills and coal mines will be discussed separately.

The majority of these plants are situated in the large cities in the heavily populated area, such as along the Miami, Wabash and Ohio Rivers. Thus, it is difficult to separate the effects of the industrial waste from those of the domestic sewage that is entering the stream at the same location. Often, industrial wastes enter the city sewers. The most satisfactory way to determine the effects of industrial effluents is to study small streams on which are located isolated plants. Increase in temperature due to hot effluents must be considered in addition to the chemical nature of the wastes.

Oil and gas refineries are found along the length of the Elk River, from Sutton to the junction with the Kanawha at Charleston. An isolated refinery is found at Huntington, W.Va., at the mouth of the Big Sandy. While the most prominent effect of the pollution is severe tastes and odors in local water supplies, there is an important effect on the fish (see also Shelford[9]). The Huntington plant causes the flesh of the fish at the mouth of the Big Sandy to taste of petroleum. The pollution along the Elk River has contributed to the absence of fish in that stream (September). The plankton of the Big Sandy is too low to draw any conclusions as to the effect of oil from the Huntington refinery on these organisms. The Elk River plankton is also low, but as the entire river is affected, it is not possible to obtain unaffected samples for comparison.

The effect of coal washeries is shown along the Tug Fork of the Big Sandy. These detract greatly from the suitability of this stream and many small tributaries for fish life. The water is black and a bottom layer of coal particles is deposited for miles below a washery. A few plankton forms, such as Navicula, Chrysococcus, Cryptomonas and Chlamydomonas, are present. These streams are alkaline.

A paper mill and tanneries on the Clarion River, a tributary of the Allegheny in Pennsylvania, discolor the water for many miles downstream. The Allegheny itself was colored for a considerable distance below the entrance of the polluted tributary. The plankton population of the Clarion at Cooksburg in July, 1939, consisted of fair numbers of Mallomonas, Chrysococcus, Chlamydomonas and Peridinium. There was a large mixed fish population. The flesh of the fish was tainted, making it inedible. A paper plant below Nashville, Tenn., apparently does not affect the plankton of the Cumberland River, although the stream is blackened.

Another type of pollution, consisting of cellulose and lignin fibers, resulting from paper and strawboard manufacture (the Wabash watershed and others), may clog the gills of fish, causing death; may increase the turbidity to the point of affecting the plankton; may form a sludge layer on the bottom of the stream, and may eventually be attacked by specialized bacteria, and so contribute to the oxygen demand. Many types of plants discharge wastes having a large oxygen demand, resulting in the depletion of oxygen and the killing of many fish annually.

Pollution from plants manufacturing chemicals may be serious in some localities. A plant on the Kanawha River, above Charleston, W. Va., has been the subject of a report by Ellis.(10) Another source of industrial pollution upon which data collected during the present survey is insufficient is brine pumpage from oil wells. This is serious, as fresh water organisms in general are not adapted physiologically to withstand heavy salt concentrations (see Ellis[11]). Tannery wastes may also be important in some localities.

Acid Pollution

The entrance of sulfuric acid from active and abandoned coal mines is one of the most important problems of stream pollution throughout the Ohio River Basin. Many abandoned coal mines that have not been sealed are daily pouring tons of sulfuric acid (formed by oxidation of iron sulfides) into these streams (Hodge[12]). Many of the active mines are working only part of the year and, unless pumping is carefully controlled when operations are resumed, a very heavy load of acid may be discharged into the watercourse. The acidity of acid mine drainage streams has been known to reach pH 2. This high acidity eliminates all fish, and only a few plankton forms exist.(1) Euglena mutabilis may grow in sufficient numbers to form a bright green carpet over the entire bed of small acid streams of pH 4 or less.

Acid streams are characterized by a deposit of yellow to brownish precipitate (iron oxide) that covers the bottom. This deposit may remain long after sealing has prevented air from entering the polluting mines and the source of acid thus eliminated. The bottom of the stream, therefore, remains unsuitable for egg deposition and development of fish and their food organisms, long after the water acidity has been corrected.

The acid drainage, chiefly from mines but also to a lesser extent from the steel mills near Pittsburgh, Wheeling and Steubenville, lowers the pH of the Ohio River to 6 or less as far downstream as Marietta, Ohio, and is an important factor in the low plankton population in the upper portion of the Ohio River, and the cause of downstream fish migration.

Stream Zones

A summary of the observations over the Ohio River watershed shows that streams and regions of streams may be divided into the following five types of zones, according to the dissolved oxygen, pH, plankton and fish data:

(1) Zone of heavy organic pollution: dissolved oxygen not higher than 3 p.p.m. even during the daytime; plankton volume variable, principally composed of Class II organisms; pH tending toward acidity. Fish mostly absent, occasionally buffalo, carp and sunfish.

(2) Zone of intermediate pollution: dissolved oxygen between 3 and 5 p.p.m. in the daytime; plankton volume is higher than in (1), with an increasing number of chlorophyll-bearing forms, although still composed largely of Class II organisms; Oscillatoria and other blue-green algae common, and a growth of green algae commencing to appear along the stream margin; pH slightly higher. Fish, in addition to carp and buffalo, are more abundant but show a tendency to sickness, deformity and parasitization.

(3) Fertile zone: dissolved oxygen not below 5 p.p.m. and subject to diurnal fluctuations; plankton over 1 M.p.p.m. (usually several M.p.p.m.), and largely green forms, of the Intermediate group, marginal growth of algae very noticeable in some places; pH alkaline and tending to rise, especially during sunny periods. Fish are variable, plentiful and healthy; large numbers of suckers, sheepshead, catfish and other market fish are present.

(4) Game fish zone: dissolved oxygen above 5 p.p.m., and usually approximating saturation values; plankton usually between 0.3 and 1.0 M.p.p.m., with Class II forms scarce; pH neutral to alkaline. Game fish (basses and perches, pike, etc.) and forage fish predominate.

(5) Poor fish zone, due to (a) natural conditions, or (b) acid pollution: (a) Naturally poor fish zone: dissolved oxygen above 5 p.p.m. and usually approximating saturation values; plankton less than 0.3 M.p.p.m. and consisting almost entirely of Class I organisms. Fish are mainly the game fish types. Streams that may be classified by the fisherman as "good" trout streams are, by the above biological standards, "poor" streams, i.e., infertile and relatively low in biological population. (b) Acid polluted zone: the pH is variable, and the water is sometimes acid. If the stream is highly acid, there may be no fish at all.

The (5-a) type of stream is characteristic of the tributaries coming to the Ohio from the south, where the winter period is not marked, so that there is generally a lower level of, and less seasonal fluctuation in, the aquatic life. It is also true that these streams usually have relatively rocky, infertile watersheds, and are often of the (5-b) type or subject to acid pollution.

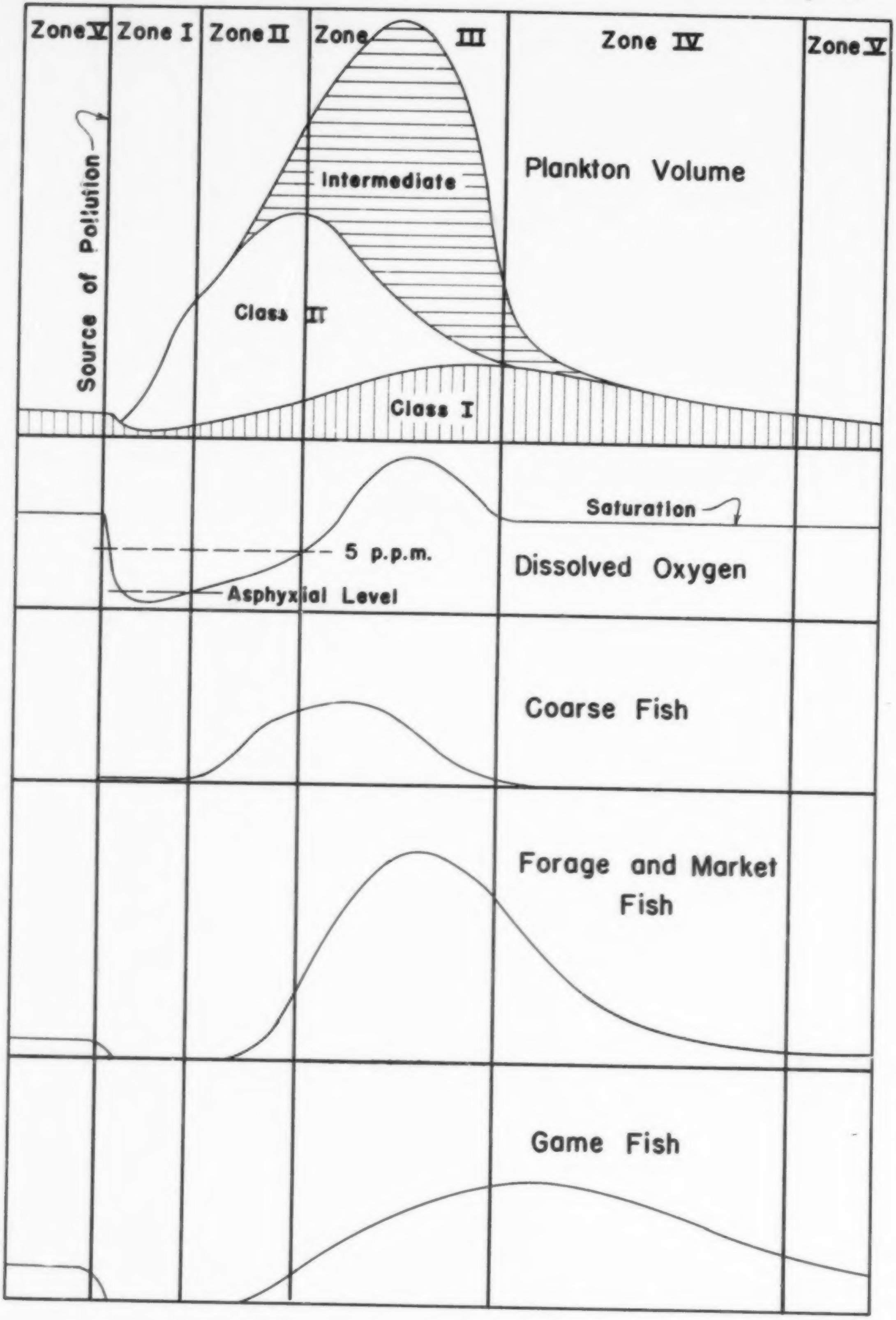
These relationships of the different zones are illustrated graphically in Figure 14. The plankton curve shows the dependence of Class II organisms upon a rich food supply and that of the Intermediate forms upon a less concentrated medium. Pollution affects the Class I organisms to a certain extent, but they are less affected by either favorable or unfavorable conditions than are the members of either of the other two groups of planktonts. For this reason they are the characteristic forms of "clean waters," as well as persisting through polluted areas.

In the region where the oxygen levels lie between asphyxial values and 5 p.p.m., fish normally found in oxygen-poor situations predominate (carp, buffalo). Fish of other types are abnormal under these conditions. Occasional abnormal fish may be found in situations where the dissolved oxygen is over 5 p.p.m., when the upstream pollution is very intense. The field results show that the 5 parts per million level seems to form a natural dividing line between good and bad fish conditions, corroborating the findings of Ellis.(11) Under certain conditions, the level may be set higher, but there is no evidence that it should be set appreciably lower.

The zones illustrated in Figure 14 are shown as possible phases in a continuous situation, although it is understood that in a given stream certain zones may never appear. The Cumberland River, for example, is an almost diagrammatic illustration of the condition depicted, with Nashville serving as the site of pollution. The Miami River, on the other hand, from Dayton downstream, falls entirely in zones (1), (2) and (3). The Wabash River watershed lies in generally fertile, glaciated territory, and its unpolluted regions correspond to zone (4) conditions. Mountain streams, acid streams and, in general, the infertile southern streams in their unpolluted reaches, correspond to zone (5). Light pollution may improve them biologically at local points.

The zone into which a given point of a stream may fall will vary with conditions. During spring high water, for example, zone (1) and (2) conditions are scarce. As the year advances and low-flow conditions set in, the polluted areas

Fig. 14


Zone V
Zone I
Zone II
Zone III
Zone IV
Zone V
Source of Pollution
Plankton Volume
Intermediate
Class II
Class I
Saturation
5 p.p.m.
Dissolved Oxygen
Asphyxial Level
Coarse Fish
Forage and Market Fish
Game Fish

are more distinct. It should be stressed that it is the summer low-water period that is critical to the fish population of a stream, and not the favorable high-water conditions. A period which exterminates a fish population may be only one day of the year, but it is not compensated by the tolerable conditions of the other 364 days. Likewise, a single epidemic of a waterborne disease renders insignificant the years between it and the previous outbreak.

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EXPLANATION OF TABLES

Mile	Refers to the distance from the junction of the stream with the Ohio, except the White River (Table 14) where it refers to the distance from its junction with the Wabash. The mileage of the Ohio River is taken from Pittsburgh, Pa.
Samp.	Samples taken.
Volume:	Plankton in thousands of parts per million.
T	Total plankton M.p.p.m.
I	Class I organisms M.p.p.m.
II	Class II organisms M.p.p.m.
Ave.	Average volume, determined by dividing the total volume of plankton by the number of samples; or the total number of organisms of the various groups, divided by the number of samples; or the total B.coli, B.O.D., D.O., Tby., pH, Temp., divided by the number of samples.
Max.	Highest value obtained during period under question.
Min.	Lowest value obtained during period under question.
Chr.	Chrysophyceae, numbers per ml.
Cry.	Cryptophyceae, numbers per ml.
Chl.	Chlorophyceae, numbers per ml.
Myx.	Myxophyceae, numbers per ml.
Bac.	Bacillarieae, numbers per ml.
Eug.	Euglenophyceae, numbers per ml.
Pro.	Protozoa, numbers per ml.
B.Coli	Coliform bacteria, most probable numbers.
B.O.D.	Biochemical oxygen demand, 5 days at 20 °C., in parts per million.
D.O.	Dissolved oxygen, parts per million.
Tby.	Turbidity, parts per million.
Temp.	Temperature, degrees Centigrade.

TABLE I

BIG MIAMI RIVER

Station	Mile	Date 1939	No. of Samp.		Volume			Chr.	Cry.	Chl.	Myx.	Bac.	Fug.	Pro.	B. Coli	BOD.	D O.	Tby.	pH	Temp.
					T	I	II													
Cleves	4.2	5-16 to 12-12	22	Ave.	3.0	.93	.63	103	47	409	11	996	23	18	217	3.61	8.70	60	7.9	17.0
				Max.	9.8	4.6	3.6	584	504	1045	46	7857	84	52	930	5.34	10.00	310	8.3	26.0
				Min.	.21	.07	.05	20	0	28	0	56	0	0	21	1.25	6.67	8	7.6	5.0
Venice	24.8	5-1 to 6-28	6	Ave.	8.2	3.5	1.3	84	169	972	7	3206	73	41	303	4.58	8.41	30	8.1	22.3
				Max.	16.9	7.7	2.7	352	340	2384	36	9044	276	84	930	5.84	9.82	40	8.3	26.5
				Min.	4.7	.38	.66	4	60	116	0	260	4	18	36	2.57	6.61	20	8.0	14.0
Hamilton Above	35.9	6-28 to 9-15	4	Ave.	5.6	1.6	1.4	48	144	651	22	2255	224	26	389	3.45	5.77	-	7.7	24.9
				Max.	15.8	5.0	4.8	124	476	1448	36	7440	708	62	930	4.20	6.43	-	7.7	26.5
				Min.	1.8	.04	0	6	4	152	4	36	28	0	46	2.31	4.78	-	7.6	23.5
Hamilton Below	30.4	7-21 to 10-27	6	Ave.	5.2	1.4	2.2	108	72	611	41	2047	119	85	2747	5.02	4.93	-	7.6	23.5
				Max.	8.4	4.2	4.7	216	138	898	84	6384	162	292	11000	11.72	6.95	-	7.8	27.5
				Min.	.76	.06	.34	15	4	60	8	36	62	12	430	1.46	1.90	-	7.5	19.0
Middletown Above	57.0	6-27 to 9-29	4	Ave.	3.0	1.1	.4	99	106	558	31	1522	84	24	257	4.51	8.44	-	7.7	23.1
				Max.	8.4	2.1	2.7	224	293	1646	64	3254	153	40	750	7.43	12.07	-	7.9	25.0
				Min.	1.0	.25	.32	16	16	68	2	36	40	3	36	2.38	7.05	-	7.4	20.5
Middletown Below	50.8	6-28 to 10-27	7	Ave.	4.3	.96	1.8	75	65	492	18	1313	61	20	1326	5.70	5.26	-	7.7	23.9
				Max.	10.2	1.8	6.5	204	100	1184	56	3492	252	40	4600	9.60	6.19	-	7.9	26.5
				Min.	1.3	.15	.09	0	8	52	0	20	4	4	390	2.87	3.54	-	7.5	19.0
Franklin Above	62.8	7-11 to 9-14	6	Ave.	7.6	.95	4.8	57	74	488	43	880	271	65	573	3.38	7.43	-	8.0	23.5
				Max.	29.1	2.3	23.6	168	124	874	56	88	796	116	2400	4.17	7.57	-	8.2	26.5
				Min.	1.7	.46	1.1	0	20	72	12	32	64	4	36	2.28	7.13	-	7.9	22.0
Franklin Below	59.6	7-11 to 10-26	7	Ave.	8.3	1.0	4.2	168	135	726	54	991	225	93	4472	5.00	6.15	-	7.8	23.4
				Max.	22.2	1.3	18.6	680	195	1268	89	2364	563	276	11000	8.50	7.05	-	7.9	26.5
				Min.	2.9	.73	.07	9	60	78	0	74	40	16	91	2.72	4.10	-	7.6	22.0
Miamisburg Above	71.6	6-27 to 10-26	9	Ave.	8.0	2.1	2.2	88	133	464	79	1001	146	35	558	2.94	7.71	-	8.1	23.0
				Max.	15.0	10.7	12.4	322	456	876	244	2834	186	68	2400	4.06	9.50	-	8.2	26.5
				Min.	1.4	.19	1.5	4	12	76	8	56	32	4	91	1.86	6.83	-	8.0	17.0
Miamisburg Below	66.5	6-27 to 10-26	9	Ave.	4.9	.79	2.3	59	113	453	29	612	200	42	2214	4.22	5.88	-	7.9	23.0
				Max.	10.9	1.3	9.0	96	436	1476	102	2368	578	100	11000	6.73	6.97	-	8.0	26.0
				Min.	1.2	.20	.30	3	16	45	4	0	32	3	430	2.41	4.70	-	7.7	17.0
Phoneton	97	7-24	1		5.7	2.9	.28	12	34	684	74	958	59	4	-	-	-	-	8.0	25.0
Tippecanoe City, Above	108	7-24	1		4.8	.96	.64	260	0	1084	72	1644	12	292	29	5.36	5.96	48	7.9	22.5
Below	103	"	1		6.5	1.3	.33	216	8	1398	215	2208	32	48	460	4.46	4.64	37	7.8	24.0
Troy Above	114	9-14	1		4.8	.76	1.6	88	4	1097	268	1346	140	0	36	4.99	10.67	35	8.3	27.0
Below	112	"	1		2.4	.48	.77	52	4	632	140	716	64	0	43	3.59	3.09	25	8.0	27.0
Piqua Above	123	9-13	1		1.6	.96	.16	144	4	436	120	1420	44	12	93	2.08	10.80	35	8.3	21.0
Below	120	"	1		1.6	.24	.29	128	8	420	76	588	56	8	2400	7.64	7.61	25	8.1	13.5
Sidney Above	137	9-13	1		1.2	.67	.17	200	0	220	24	388	72	4	9.1	2.09	9.02	38	8.1	19
Below	132	"	1		14.0	12.1	1.0	140	0	132	100	3618	80	0	11000	8.44	7.27	25	8.1	20
Loganville "	155	7-25	1		1.4	.04	.83	0	2	72	72	38	24	2	-	-	-	-	7.6	26
Russel Point	164	7-25	1		1.2	.12	.28	9	9	152	540	138	39	3	-	-	-	-	7.8	-

TABLE 1, cont.

WHITEWATER RIVER

Station	Mile	Date 1939	No. of Samp.	Volume T	Volume I	Volume II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. Coli.	BOD.	D O.	Tby.	pH	Temp.
Harrison	Above	7-13	1	2.9	.38	.33	40	188	772	0	152	80	24	15	0.94	7.77	-	-	24.0
	Below	"	1	5.1	.79	.54	24	568	1708	8	284	86	8	93	1.31	8.00	-	-	23.5
Brookville																			
East Fk.	Above	7-13	1	4.4	.94	1.2	12	164	548	0	484	156	0	24	0.99	9.08	-	-	23.5
West Fk.	Above	7-13	1	3.1	2.0	.16	20	80	312	4	218	30	12	9.3	.39	9.30	-	-	24.5
	Below	7-13	1	.62	.18	0	16	63	254	3	134	23	0	930	1.07	7.85	-	-	23.5
Connersville	Below	8-9	1	.98	.55	0	36	60	60	0	168	12	0	430	1.60	6.95	-	-	24.0
Cambridge City																			
	Above	7-12	1	1.6	1.4	1.0	4	8	32	0	344	12	4	93	0.90	10.34	-	-	22.0
	Below	7-12	1	1.7	1.1	.29	10	60	140	5	375	50	0	93	0.90	11.51	-	-	22.5
Hagerstown	Above	7-12	1	.57	.51	0	0	0	15	0	165	0	0	23	2.05	11.40	-	-	23.0
	Below	7-12	1	.99	.85	.06	25	5	30	0	343	30	10	29	0.77	8.75	-	-	20.5
Richmond	Above	7-12	1	7.1	6.7	.24	0	30	45	0	530	25	10	93	1.34	7.78	-	-	23.5
	Below	7-12	1	16.2	12.1	3.6	5	70	95	5	1580	300	5	150	2.75	7.97	-	-	22.0
STILLWATER RIVER																			
Englewood	Above	7-24	1	3.1	.55	.76	15	101	444	15	42	147	0	-	-	-	-	7.8	-
W. Milton	Above	9-15	1	.92	.44	.18	336	0	248	0	752	24	12	23	3.03	8.15	37	8.0	22.5
	Below	"	1	1.1	.45	.02	498	0	187	28	492	11	8	93	3.02	6.88	51	7.9	22.5
Covington	Above	9-20	1	.87	.42	.24	172	8	32	0	4	8	12	24	2.12	6.45	70	8.0	15.0
	Below	"	1	.79	.20	.09	280	25	116	4	76	20	16	910	2.08	4.84	33	7.9	17.0
MAD RIVER																			
Springfield	Above	7-25	1	.24	.23	00	0	3	0	0	105	0	3	-	-	-	-	-	-
	"	7-24	1	.59	.58	00	0	40	30	0	255	0	0	-	-	-	-	7.8	20.0
Springfield	Below	9-12	1	6.2	6.2	00	0	4	4	8	628	4	4	460	2.44	8.38	10	7.8	18.0
Urbana	Above	9-14	1	2.6	2.6	00	0	0	8	0	260	0	0	15	1.40	8.94	10	7.9	20.0
	Below	"	1	1.9	1.9	00	0	0	0	0	649	0	0	430	2.65	7.93	10	7.9	21.5
	Below	7-25	1	2.1	2.1	00	12	0	0	0	222	0	3	-	-	-	-	7.8	22.0
West Liberty		7-24	1	.31	.23	00	0	0	12	0	90	3	0	-	-	-	-	7.8	25.0

TABLE 2

LITTLE MIAMI RIVER

Station	Mile	Date 1939	No. of Samp.		Volume			Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD	D O	pH	Temp.
					T	I	II												
Beechmont		5-5		Ave.	4.0	.77	.86	517	86	791	11	335	80	32	3155	5.53	6.25	7.6	17.1
		to	14	Max.	14.7	2.0	4.3	2302	196	6724	40	1720	304	64	1100	13.62	12.50	7.8	25.5
		11-20		Min.	.75	.13	.02	0	0	54	0	0	0	0	91	1.63	1.53	7.5	0.0
Milford Above	14.2	11-20	1		6.0	5.9	.04	88	24	12	0	444	0	8	24	1.32	11.84	8.0	7.0
Milford	13.5	7-18		Ave.	1.8	1.1	.21	34	65	164	7	1101	24	21	158	1.70	7.54	-	24.0
		to	3	Max.	3.7	2.6	.36	88	116	324	20	3136	32	40	230	1.67	8.00	-	26.5
		8-15		Min.	.76	.29	00	7	20	44	0	63	0	0	93	1.41	7.10	-	22.5
Milford Below	13.3	8-28		Ave.	2.3	.73	.27	449	39	951	11	103	46	24	54	2.43	9.51	8.1	16.5
		to	3	Max.	2.6	2.0	.65	748	60	2262	24	304	76	30	93	3.09	11.58	8.2	23.5
		11-20		Min.	2.2	.05	.02	117	24	44	0	0	0	8	23	1.32	7.98	8.0	6.0
Loveland Above	24.6	7-17		Ave.	4.1	.74	.80	262	100	1239	6	131	85	8	19.4	2.71	10.06	8.0	18.3
		to	4	Max.	7.4	1.5	1.7	480	296	2934	24	372	171	12	36	4.48	12.20	8.1	24.0
		11-20		Min.	1.5	.07	.10	48	28	68	0	12	7	2	.73	1.73	7.90	7.9	6.5
Loveland Below	23.6	7-17		Ave.	3.6	1.7	.30	191	77	474	4	466	36	12	24.8	1.97	10.18	8.1	18.2
		to	3	Max.	4.7	4.2	.37	432	159	924	12	1169	60	20	36	3.12	11.90	8.1	25.0
		11-20		Min.	2.4	.15	.26	12	24	68	0	6	8	4	2.3	1.06	7.93	8.0	7.0
Kings Mills	31.2	8-2		Ave.	2.0	.71	.58	111	46	456	8	132	64	18	14.7	1.46	9.09	8.0	19.3
		to	4	Max.	4.4	2.0	.25	160	96	1620	4	232	112	52	36	1.82	11.34	8.1	24.5
		11-22		Min.	.62	.21	00	60	12	44	0	8	1	4	4.3	1.03	7.83	7.9	6.5
S.Lebanon	33.8	8-2		Ave.	2.1	.27	.79	153	75	272	0	57	81	8	45	1.32	7.85	7.9	25.0
		to	3	Max.	4.9	.43	1.8	264	174	724	0	148	112	20	91	1.58	8.17	7.9	28.5
		9-27		Min.	.47	.11	.16	4	12	36	0	0	64	4	9	1.05	7.40	7.9	23.0
Yellow Springs Above	82.0	8-25		Ave.	.92	.50	.04	8	7	79	0	29	4	3	19.6	0.82	8.53	7.8	13.8
		to	4	Max.	1.4	1.3	1.05	16	16	228	0	72	12	8	46	0.99	10.07	8.1	21.5
		11-17		Min.	.10	00	.01	0	0	4	0	0	0	0	.91	0.61	7.37	7.6	7.0
Yellow Springs Below	81	9-22		Ave.	3.2	.10	.19	11	12	165	0	40	10	7	9.74	0.88	10.53	7.9	9.5
		to	3	Max.	9.2	.16	.48	12	16	474	0	62	28	12	24	1.26	12.98	8.0	14.0
		11-17		Min.	.19	.05	.05	8	0	0	0	16	0	0	.91	0.54	8.48	7.9	4.5
S. Charleston	96.5	9-7			.94	.62	.26	28	56	24	0	192	24	8	36	1.53	6.55	7.9	19
	96.5	10-4			35.9	1.2	31.2	0	4	15	0	636	2830	0	110	5.53	9.50	8.3	20.5
	99	9-7			2.2	2.0	.08	16	0	24	16	610	30	12	150	4.35	3.95	7.9	18.0
	99	10-4			.74	.66	.06	0	0	16	4	136	72	0	460	2.49	7.53	7.9	18.
								EAST	FORK										
South Milford		7-18		Ave.	1.5	.51	.28	1452	82	183	0	46	145	6	37.5	2.04	7.81	7.6	19.3
		to	5	Max.	3.3	1.4	.90	6492	268	336	3	51	446	15	73	2.40	11.24	7.7	23.5
		11-21		Min.	.14	.02	00	36	4	20	0	4	16	0	1.5	1.80	5.63	7.6	7.5
Batavia Below		7-31		Ave.	2.61	.28	1.33	1651	133	59	5	28	140	35	162	2.88	5.46	7.5	16.3
		to	3	Max.	7.1	.56	2.0	2360	356	20	8	80	356	44	430	3.84	7.02	7.5	23.5
		11-21		Min.	.29	.02	1.8	40	0	4	0	0	16	24	9	1.37	4.43	7.5	6.5
Williamsburg Above	46.2	6-30		Ave.	1.2	.73	.5	1220	80	247	2	23	106	28	18	2.42	7.98	7.6	18.3
		to	4	Max.	3.9	1.4	1.7	2927	144	568	8	48	240	100	36	3.53	10.37	7.7	25.0
		11-21		Min.	1.6	.08	.21	40	24	22	0	0	0	0	2.4	0.66	6.52	7.5	6.5
Williamsburg Below	45	6-30		Ave.	1.7	1.3	1.	535	330	314	0	36	96	15	341	3.99	6.85	7.5	19.3
		to	5	Max.	8.9	5.0	2.9	2236	1344	716	0	84	388	28	1100	10.98	7.52	7.6	25.0
		11-21		Min.	.44	1.03	.36	12	24	132	0	0	8	8	36	1.45	6.16	7.4	6.0
Lynchburg Above		10-9	1		1.7	.1	.55	1106	4	24	0	8	152	32	23	3.50	2.53	7.7	20.0
Below		"	1		.37	.01	.19	112	4	16	0	0	72	12	4.3	3.16	5.56	7.8	21.0

TABLE 2, cont.

TURTLE CREEK

Station	Mile	Date 1939	No. of Samp.		Volume			Chr.	Cry.	Chl.	Nyx.	Bac.	Eug.	Pro.	B. coli	BOD	D.O.	pH	Temp.
					T	I	II												
South Lebanon		7-19		Ave.	26.2	.30	.73	50	61	618	0	99	23	28	135	3.02	7.00	7.9	20.0
	34.2	to	3	Max.	77.3	.72	.38	100	92	1716	0	330	32	76	230	5.37	7.27	7.9	22.5
		9-27		Min.	.35	.07	.02	3	28	72	0	12	8	0	24	1.22	6.60	7.9	16.5
Lebanon		7-19		Ave.	5.5	1.5	.98	291	850	641	0	220	122	30	84	2.30	6.35	7.5	16.8
Above		to	5	Max.	18.3	3.5	2.3	760	3964	3592	3	844	464	52	230	4.62	8.00	7.6	21.5
		11-22		Min.	1.0	.60	0	6	0	32	0	4	12	8	2	1.33	5.42	7.5	8.0
Lebanon		7-19		Ave.	1.3	.44	.56	6	[illegible]	45	11	140	29	66	43,000	25.04	2.44	7.5	17.1
Below	37.8	to	4	Max.	2.4	1.6	1.6	16	3	87	24	495	44	208	150000	79.30	4.70	7.5	21.5
		11-22		Min.	.37	.03	0	0	0	8	0	16	16	4	2400	2.32	0.00	7.5	7.0
CAESAR CREEK																			
Jamestown		8-14		Ave.	2.8	1.2	.53	6	20	212	28	406	176	336	568	5.89	3.25	7.5	20.0
Above	78.5	to	2	Max.	4.3	1.8	.65	8	40	336	56	608	292	668	1100	8.70	3.42	7.5	23.0
		8-25		Min.	1.3	.65	.40	4	0	8	0	204	60	0	36	3.07	3.07	7.5	17.0
Jamestown		8-14		Ave.	2.4	.5	1.1	0	6	164	0	163	180	2	345	5.12	2.50	7.7	20.3
Below	76.5	to	2	Max.	2.6	.86	1.2	0	12	320	0	280	252	4	460	5.28	3.14	7.7	22.5
		8-25		Min.	2.2	.14	.88	0	0	8	0	45	72	0	230	4.95	1.85	7.7	18.0
SHAWNEE CREEK																			
Xenia	80.6	6-29		Ave.	2.9	.62	2.0	4	7	63	2	149	58	6	217	1.52	7.03	8.0	16.8
Above		to	7	Max.	12.0	1.9	10.8	20	40	144	8	444	304	20	1100	2.91	11.34	8.1	24.5
		11-17		Min.	.34	.02	0	0	0	0	0	12	0	0	4.3	1.01	4.46	7.8	6.5
Xenia	76.1	6-29		Ave.	.98	.52	.05	5	0	98	0	185	12	1	3147	4.71	4.17	7.5	14.9
Below		to	4	Max.	2.0	1.8	.13	12	0	368	0	640	38	3	11000	5.38	7.27	7.6	21.5
		11-17		Min.	.11	.07	00	0	0	0	0	28	0	0	43	3.69	2.44	7.3	7.5
Xenia	76.1	7-17		Ave.	2.2	.86	1.1	2	3	33	13	176	18	5	8420	6.55	5.76	7.9	15.7
Below		to	6	Max.	8.4	2.6	5.4	4	12	88	36	944	48	16	46000	7.83	6.53	8.0	23.5
		11-17		Min.	.48	.08	[illegible]	0	0	0	0	36	0	0	240	5.61	3.87	7.7	8.0
LYTLE CREEK																			
Wilmington		6-29		Ave.	3.3	1.0	1.3	10	45	111	[illegible]	127	56	21	689	3.19	5.62	7.5	20.2
Above	66.5	to	6	Max.	7.4	2.0	4.3	40	224	504	4	284	222	72	2400	8.94	9.08	7.5	24.5
		10-2		Min.	.25	.16	0	0	0	12	0	32	16	0	91	1.04	0.51	7.5	15.0
Wilmington		6-29		Ave.	3.2	1.4	.05	7	16	231	[illegible]	413	73	6	1116	6.71	8.08	8.0	20.9
Below	59.5	to	6	Max.	4.7	3.8	1.6	20	92	856	4	760	276	12	4600	23.40	12.90	8.2	25.5
		10-2		Min.	.92	0	0	0	0	24	0	32	21	0	36	1.32	0.21	7.7	13.5

TABLE 3

LICKING RIVER

Station	Mile	Date 1939	No. of Samp.		Volume T	I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli.	BOD.	D.O.	Tby.	pH	Temp.
Latonia	5.5	5-3		Ave.	.99	.15	.14	453	22	192	0	545	17	12	157.2	1.56	8.34	-	7.66	18.6
		to	9	Max.	3.1	.28	.39	3472	71	704	0	4526	54	44	1100.0	2.13	11.40	-	7.8	26.0
		11-13		Min.	.18	.02	00	0	0	24	0	4	0	0	2.3	0.97	6.50	-	7.5	5.0
Falmouth	51.5	5-3		Ave.	.64	.09	.15	36	14	93	0	26	20	4	73.9	1.52	7.58	-	7.8	21.2
		to	7	Max.	2.45	.23	.67	97	28	320	4	76	68	12	460.0	2.03	9.55	-	7.8	26.0
		9-18		Min.	.22	.01	00	2	0	20	0	0	2	0	2.3	1.01	7.58	-	7.8	15.5
Claysville Above	65	9-18	1		.33	.02	.01	8	20	80	0	0	12	0	46.0	1.71	8.48	54	7.9	26.0
Blue Lick Above	100	9-18	1		.38	.04	.02	104	4	68	0	8	40	12	2.3	2.32	5.92	32	7.5	23.5
Below	96	9-18	1		.10	00	.04	32	0	16	8	0	20	4	2.4	1.33	6.27	37	7.4	23.5
Flemingsburg Below		9-19	1		5.1	.04	3.0	0	48	124	28	0	2184	20	150.0	7.96	5.90	36	7.8	20.0
Morehead Below		9-19	1		9.1	.68	1.1	1172	604	4	0	0	4144	8	23.0	3.30	2.16	11	6.9	20.5
SOUTH FORK																				
Falmouth		5-9		Ave.	3.3	.21	1.37	23	79	585		21	126	7	67.7	2.17	7.87	-	7.8	23.5
		to	8	Max.	13.8	.67	7.2	84	160	1752	12	103	666	16	240.0	3.31	9.64	-	-	27.5
		9-18		Min.	.44	.02	.07	0	0	28		0	5	0	2.3	1.14	6.92	-	-	20.0
Farmers	170	9-19	1		.56	.08	.10	1168	20	44	4	0	12	4	3.6	0.63	6.49	14	7.3	20.5
Lair Above		9-13	1		2.9	1.09	.34	156	72	2716	0	4	109	8	3.6	2.15	5.44	76	7.9	21.5
Below		9-13	1		3.6	.04	.89	160	32	1780	0	3	163	76	3.6	1.63	6.70	76	7.8	24.5
Cynthiana Above		9-13	1		.85	.06	.23	80	36	380	0	8	84	4	23.0	1.53	4.24	39	7.6	22.0
Below		9-13	1		4.7	.04	2.4	12	36	120	0	40	308	8	2.0	2.99	12.67	22	8.6	25.5
Paris Above		9-12	1		3.1	00	1.3	0	36	560	0	0	104	16	3.6	1.49	6.87	12	7.8	24.5
Below		9-12	1		23.4	.50	.83	0	240	892	0	13	76	22	36.0	5.30	5.06	30	7.8	20.5
Below		9-22	1		17.4	.17	7.8	0	184	524	0	0	2206	12	46000.	41.15	0.0	51	7.4	22.0
Mt. Sterling Above		9-12	1		.24	.02	.0	45	0	132	4	4	0	0	36.0	5.39	9.10	80	7.9	20.5
Below		9-22	1		.11	00	.01	4	0	20	0	0	12	0	110000.0	41.07	0.00	28	7.5	15.5
STRODES CREEK																				
Winchester Above		9-12	1		.11	.01	00	128	4	4	0	0	8	4	36	3.03	4.11	20	7.6	16
Below		9-22			.12	.10	.02	8	4	16	0	32	4	0	3.6	3.12	3.55	17	7.6	22
BRUSH CREEK																				
Carlisle Below		9-13	1		.15	00	.07	4	0	12	0	4	16	0	23.	1.52	7.37	15	7.6	25.0

TABLE 4

KENTUCKY RIVER

Station	Mile	Date 1939	No. of Samp.			Volume														
					T	I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B.coli	BOD.	D.O.	Tby.	pH	Temp.
Carrollton		5-2		Ave.	1.3	.26	.06	16	25	146	4	114	17	9	4.41	1.52	7.39	47	7.6	20.4
		to	21	Max.	10.2	1.4	.46	100	116	1256	44	540	140	24	11.0	3.39	9.90	340	8.1	26.
		11-30		Min.	.13	.01	00	0	0	0	0	12	0	0	0.39	0.63	5.41	6	7.3	9.
Gratz	29	8-21	1		1.6	.08	.06	8	64	176	0	48	17	0	-	-	-	-	6.9	26.
Frankfort																				
4 mi. Below	63	9-27	1		1.6	1.1	00	8	8	36	8	87	4	64	93.0	2.57	3.39	18	7.3	23.5
Dam	65	9-27	1		1.3	1.3	00	0	4	14	4	2098	0	24	240.0	2.40	6.56	13	7.8	23.5
1 mi. Above	66	9-27	1		.92	.59	00	0	20	12	0	1542	4	4	43.0	2.05	8.74	15	8.1	24.
Camp Nelson	135	9-28	1		.99	.50	00	0	48	96	4	24	0	8	3.6	1.83	7.64	12	7.7	23.
Irvine	217.1																			
Below		9-29	1		.09	.01	.04	96	0	0	0	0	24	0	9.3	1.58	5.71	-	7.2	25.
Ravenna	221																			
Above		9-29	1		1.2	.72	.16	1128	4	20	0	0	30	8	2.3	2.95	7.40	-	7.1	24.5
Beattyville	254.8																			
Above		9-29	1		.34	.03	.19	425	0	0	0	0	60	4	240.0	2.06	7.46	-	7.3	25.
Below		9-29	1		.24	.04	.07	332	4	48	0	0	45	0	9.3	2.21	6.71	-	7.2	24.5
Jackson	305																			
Above		10-17	1		.12	.02	00	276	4	4	0	0	0	4	9.3	1.51	10.33	16	7.5	11.5
Below		10-17	1		.45	.13	.26	1082	36	16	12	0	35	12	3.6	3.25	7.97	34	7.6	11.5
Chavies	335.8																			
		10-17	1		.14	.07	.07	1124	8	0	0	0	4	0	0.9	1.91	10.96	-	7.6	17.
Hazard																				
Above		10-16	1		.41	.29	00	1380	28	28	4	0	12	8	46.0	2.26	9.23		7.7	9.
At		10-16	1		1.24	.19	.03	800	12	4	20	0	16	4	150.0	1.62	7.89	17	7.4	9.5
Below		10-16	1		.12	.05	.05	240	0	4	24	0	8	0	4600	8.82	3.31	13	7.3	6.5
Whitesburg	404																			
Above		10-19	1		.01	00	00	4	0	0	0	0	8	0	9.3	0.98	9.84	5	7.9	10.
Below		10-19	1		.27	.20	.02	0	0	0	0	68	0	28	460.0	1.36	5.07	14	7.7	11.
								SOUTH FORK												
Manchester	299																			
Above		10-16			.21	.03	00	320	4	0	8	0	88	4	9.3	1.67	6.68	12	7.2	13
Below		10-16			.54	.11	.04	130	112	92	0	0	4	16	93.	1.91	4.52	5	7.2	9
Big Creek	299	10-6			1.7	1.3	.06	2593	8	64	0	0	48	32	.36	1.60	8.78	28	7.3	11
Jackson a	310.4	10-17			1.4	.27	.24	1200	96	20	0	48	36	22	240.	1.88	9.85	12	7.2	11
Hyden b	327.6	10-16			.02	00	00	36	0	8	0	0	0	8	7.3	.86	9.17	11	7.3	10.5
Blackey	387.6	10-20			.01	00	00	60	0	4	0	0	0	0	24	0.78	10.10	5	7.5	14.5
Neon		10-18			.85	.70	.03	28	0	36	8	276	8	4	240	3.03	8.31	14	7.9	12
Cornettsville		10-20			.12	.07	00	594	40	12	0	0	12	0	9.3	1.78	6.60	8	7.3	10.5
Haddux	314	10-17			.02	.01	00	188	0	0	0	0	0	4	4.3	0.96	10.0	15	7.8	12

a = above b = below

TABLE 5

BIG SANDY RIVER

Station	Mile	Date 1939	No. of Samp.			Volume		Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B.coli	BOD.	D.O.	Tby.	pH	Temp.
					T	I	II													
Dam 1	.3	6-14 to 11-27	18	Ave.	1.0	.07	.61	36	98	147	3	43	65	10	117.	1.36	6.72	44	7.5	24.1
				Max.	3.0	.28	2.3	213	336	512	9	200	292	32	460	2.09	8.88	250	7.8	29.
				Min.	.13	.01	00	0	0	0	0	0	0	0	7.5	0.77	4.85	5	7.1	10.
Dam 3	26.6	6-14 to 10-13	7	Ave.	.27	.14	.09	94	54	21	0	10	13	13	140.	0.89	7.84	8	7.7	24.9
				Max.	.77	.32	.21	296	328	56	4	30	26	16	240	1.14	8.20	12	8.0	29.
				Min.	.08	.01	00	0	0	0	0	0	0	0	3.6	0.53	7.39	6	7.0	19.5
TUG FORK																				
Dam 1	3.8	10-13	1		.11	.03	00	32	0	4	0	18	0	0	4.3	0.96	9.08	-	-	14.
Kermit Above		11-24	1		.29	.02	.12	248	8	48	0	0	0	4	2.3	2.48	10.81	5	7.8	6.
" Below	35.5	11-24	1		.17	.05	00	272	28	32	0	4	0	0	36.	1.87	10.77	5	7.6	6.5
Williamson																				
Above	57.1	11-19	1		.66	.66	00	140	4	40	0	16	0	12	3.6	0.82	11.56	5	7.8	7.
Below		11-8	1		.25	.05	.20	60	52	12	0	0	0	12	1100.	1.58	8.94	5	7.7	8.
Matowan	98	11-24	1		.18	.02	00	80	12	44	0	12	0	0	4.3	1.97	11.54	5	7.7	6.5
Iaeger Above	136	11-20	1		2.5	2.0	00	0	4	32	0	304	0	0	4.3	2.48	11.86	7	6.4	7.5
" Below		11-20	1		2.0	1.95	.02	12	8	12	0	536	0	4	1100.	3.18	12.42	5	8.4	8.
Welch Above	159	11-9	1		.53	.53	00	8	0	0	0	204	0	0	9.3	2.60	14.78	5	7.5	9.
Below		11-9	1		.50	.10	.40	0	0	0	0	40	0	44	460.	11.40	6.79	18	6.1	11.5
Gary	168	11-9	1		.02	.02	00	0	0	0	0	8	0	0	240.	5.76	11.26	5	7.6	9.
LEVISA FORK																				
Louisa		9-29	1		.27	.04	.12	420	0	260	0	0	4	32	0.9	0.54	7.80	-	-	22.5
Wallbridge	2.7	10-13	1		.42	.30	00	592	0	124	0	48	0	0	4.3	0.95	6.68	-	-	17.5
Paintsville																				
Above	38.6	11-28	1		.25	.05	.20	384	24	0	0	0	0	12	7.5	1.27	11.33	7	7.4	4.
Below		11-26	1		.04	.04	00	304	4	0	0	8	0	0	240.	1.70	10.98	12	7.3	4.
Van Lear		11-29	1		.46	.17	00	740	124	24	0	4	0	8	0.4	1.66	12.01	11	7.3	3.5
Prestonburg																				
Above		11-24	1		1.4	.29	1.0	1398	228	12	0	0	4	20	3.6	1.55	10.80	17	7.2	7.
Below	54.9	11-24	1		.22	.19	00	948	148	8	0	0	0	0	150.	1.57	10.61	20	7.1	7.
Boldman b	77.3	11-9	1		.18	.11	.05	784	68	8	0	4	4	8	3.6	3.39	13.41	16	7.9	12.
Pikeville a	88.5	11-9	1		.29	.27	00	3552	32	4	0	4	5	4	3.6	0.56	11.27	18	7.3	5.
" b		11-9	1		1.9	.41	1.4	4040	132	12	0	32	8	24	1100.	3.58	8.62	12	7.2	8.
Willard a		11-6	1		.64	.47	.09	1010	76	0	0	8	16	8	3.6	1.45	10.73	30	7.2	5.5

Station key: a - above b - below

TABLE 6

LITTLE SANDY RIVER

Station	Mile	Date 1939	No. of Samp.			Volume														
					T	I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B.coli	BOD.	D.O.	Tby.	pH	Temp.
Greenup	.1	6-14 to 11-24	18	Ave.	.29	.08	.11	61	37	18	0	13	6	8	167.2	0.95	7.35	43	7.4	21.1
				Max.	1.5	.66	1.2	146	264	40	4	52	36	24	1100.0	1.47	9.90	160	7.9	25.5
				Min.	.02	00	00	0	0	0	0	0	0	0	3.6	0.54	6.26	6	7.2	6.5
Grayson Above	24.	9-8 to 11-29	4	Ave.	.09	.04	.03	404	5	0	0	4	3	9	14.1	0.90	6.63	25	7.6	14.5
				Max.	.19	.07	.12	896	20	0	0	12	10	16	24.0	1.11	7.10	30	7.8	22.0
				Min.	.06	.01	00	0	0	0	0	0	0	0	9.1	0.56	6.29	22	7.5	3.0
Grayson Below		9-8 to 11-29	4	Ave.	.30	.06	.22	382	4	6	0	0	17	14	460.0	1.43	5.71	31	7.6	14.4
				Max.	.66	.14	.50	860	9	12	0	0	37	32	460.0	2.24	6.50	35	7.9	22.0
				Min.	.01	.01	00	10	0	0	0	0	0	0	460.0	0.77	4.74	22	7.3	3.0

TABLE 7

GUYANDOT RIVER

Station	Mile	Date 1939	No. of Samp.		Volume			Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B.coli	BOD.	D.O.	Tby.	pH	Temp.
					T	I	II													
Huntington		6-14 to 11-27	16	Ave.	.37	.11	.05	53	15	67	2	25	6	2	2087.	2.40	6.25	41	7.3	22.
				Max.	1.4	.65	.24	316	108	260	8	180	40	8	11000.	7.64	10.68	210	7.5	28.5
				Min.	.06	00	00	0	0	4	0	0	0	0	91.	0.90	0.08	5	6.7	7.
Chapmanville	69	12-1	1		.36	.02	00	212	4	80	0	0	0	12	30.	1.57	10.97	5	7.4	8.
Henlawson	76.8	11-28	1		.07	.04	00	392	4	8	0	4	0	0	43.	2.38	7.49	32	7.1	8.
Logan																				
Above		11-30	1		.08	.02	00	1156	0	0	0	0	8	0	75.	1.58	12.63	3	7.6	4.5
Below	81.4	11-28	1		.08	.08	00	1008	20	0	0	0	0	0	91.	1.86	8.11	20	7.1	9.
Man																				
Above		11-27	1		.11	.11	00	1580	0	0	0	4	0	0	3.6	1.96	13.31	8	7.9	5.5
Below		11-27	1		.23	.22	00	718	0	8	0	72	0	0	7.2	2.96	13.69	2	7.9	6.5
Gilbert	111	10-10	1		.02	.02	00	88	0	0	0	4	0	0	-	-	-	-	7.6	24.
Pineville																				
Below	143	11-13	1		.02	.02	00	0	0	0	0	36	0	4	430.	3.20	10.89	5	7.7	3.5
Itman	153.6	11-13	1		.42	.42	00	0	2	1	0	630	0	0	460.	4.51	10.59	2	7.7	2.5
Mullens																				
Above	157.6	11-13	1		.24	.24	00	0	0	0	0	96	0	0	-	4.51	10.59	2	7.7	3.
Below	156.0	11-13	1		.01	00	00	4	4	0	0	0	0	0	43.	3.64	9.28	7	7.7	3.

TABLE 8

KANAWHA RIVER

Station	Mile	Date 1939	No. of Samp.		Volume T	I	II	Chr.	Cry.	Chl.	Vxy.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
Pt. Pleasant	.6	8-10 to 11-27	7	Ave. Max. Min.	.68 3.7 .07	.19 1.0 00	.29 2.0 00	55 108 0	182 1112 4	61 244 0	0 4 0	278 864 0	6 36 0	6 24 0	1.6 4.3 0.4	0.78 0.89 0.69	7.34 8.53 6.24	7 12 4	7.3 7.6 6.9	18.1 27. 5.
Buffalo	21.8	7-6	1		.60	.42	.02	32	460	108	0	8	0	4	-	-	-	-	-	-
Winfield	31.1	8-10	1		1.1	.15	.84	112	160	52	0	4	12	40	-	-	-	-	6.8	26.
St. Albans Below	46.2	7-4	1		1.1	.03	.05	36	0	216	0	36	20	0	-	-	-	-	6.9	26.
Cheylan	73.7	7-4	1		.03	.01	00	0	0	28	0	8	8	0	-	-	-	-	7.1	29.
Montgomery	85.6	7-4	1		.15	00	00	0	0	60	0	0	0	0	-	-	-	-	7.1	-

TABLE 9
MONONGAHELA RIVER

Station		Mile	Date 1940	T	Volume I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	pH	Temp.
Dam #2		11	8-19	.25	00	00	0	0	290	0	0	0	0	.91	0.65	5.38	3.5	19
Dam #4		41	8-19	.60	00	00	0	0	780	0	0	0	0	.73	0.85	7.21	3.3	26
Dam #5		56	8-19	.38	00	00	0	0	472	0	0	0	0	2.1	0.54	7.30	3.7	26
Dam #6		68	8-19	.02	.02	00	5	5	0	5	85	0	0	.36	0.33	7.18	3.3	26.5
Dam #7		84	8-19	.30	.02	.06	0	0	275	0	5	5	0	.36	0.66	7.52	3.4	26
Dam #8		90	8-19	.22	00	00	0	0	280	0	0	0	0	.36	0.52	7.33	3.3	26.5
TRIBUTARIES TEN MILE CREEK																		
Mariana	a		8-21	.84	.23	.42	20	240	30	0	10	380	0	23	1.19	6.67	7.6	20.5
"	b		8-21	1.3	.45	.22	40	285	65	0	85	250	40	1100	2.95	6.66	7.5	20.5
Waynesburg	b		8-21	1.9	1.2	.27	55	875	40	40	2015	90	15	110000	9.18	0.44	7.4	22
Waynesburg	a		8-21	18.1	.74	.96	135	15	40	5	1395	320	4825	93	1.59	5.97	7.6	20.5
PIGEON CREEK																		
Bentleyville North Fk.			8-21	.04	00	00	0	0	5	0	0	15	0	3.6	0.47	7.84	6.6	15
At			8-21	5.5	1.4	3.1	175	135	135	0	845	470	10	1100.	2.49	8.35	7.6	17.5
Bentleyville Below			8-21	3.3	2.0	.85	15	115	35	5	1520	220	10	240	1.91	8.67	7.5	15.5
Cokeburg			8-21	2.8	2.2	.45	0	35	0	0	745	215	0	240	2.03	8.58	7.6	17.0
Ellsworth			8-21	.71	.28	.12	5	40	25	0	125	30	10	9.1	1.[illegible]	4.37	7.5	18.5
Youghiogheny River McKeesport			8-19	1.1	00	1.1	0	0	0	0	0	20	95	2.3	1.43	6.18	3.5	25

Station Key: a = above; b = below.

TABLE 10

ALLEGHENY RIVER

Station	Mile	Date 1940	Volume T	I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	pH	Temp.
Dam #2	6	8-20	.06	.03	00	0	0	30	0	10	0	0	2400	1.54	6.82	6.6	27
Dam #3	14	8-20	3.2	3.2	00	0	0	0	0	49	0	0	.36	0.76	6.60	4.4	28
Dam #4	24	8-20	.00	.00	00	0	0	0	0	0	0	0	.36	0.45	7.00	4.3	25.5
Mosgrove	50	8-6	2.1	1.8	.09	20	0	65	0	175	5	0	-	-	-	-	27
Dam #8	52	8-20	.64	.39	.06	25	15	70	5	145	10	5	3.6	1.42	8.10	7.4	25.5
East Brady	70	8-2	2.2	2.0	.19	0	0	55	0	80	6	6	-	-	9.67	7.4	27
Parkers Landing	83	8-5	.64	.62	00	0	0	55	0	60	0	0	-	-	10.13	7.3	27
Kennerville	110	8-5	.12	.09	00	0	0	18	6	30	0	0	-	-	-	-	27
Tionesta b	150	8-1	1.6	1.0	.06	40	0	150	15	360	15	5	-	-	-	-	-
TRIBUTARIES																	
STONY CREEK																	
Hooverville a		7-17	.37	.35	00	0	0	5	0	115	0	0	110	0.57	8.95	5.7	18
Holsopple b		7-17	.09	.02	00	18	0	6	0	6	0	0	3.6	0.36	8.71	4.7	19.5
KISKIMINETAS RIVER																	
Freeport		8-20	.57	.07	00	10	0	50	5	175	10	25	3.6	1.56	7.46	7.4	25
RED BANK RIVER		8-6	.15	.11	00	144	0	16	0	43	0	24	-	-	-	-	-
CLARION RIVER																	
Cooksburg		8-3	1.6	1.3	.10	8	0	48	8	144	0	16	-	-	-	-	24

a = above: b = below

TABLE 11
MUSKINGUM RIVER

Station	Mile	Date 1940	T	Volume I	II	Chr.	Cry.	Chl.	Myx	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	pH	Temp.	Tby.
Dam #1	0.2	6-28	.48	.10	00	5	00	45	0	85	5	5	-	-	-	-	22.5	
Dam #1	0.2	7-10	1.2	.09	00	70	15	225	0	250	25	10	-	-	-	-	23.5	
Dam #1	0.2	7-15	4.5	2.1	1.4	215	40	210	25	405	30	25	-	-	-	-	-	
Beverly	a 24	8-8	.59	.55	00	35	0	59	6	145	6	0	-	-	-	-	29	
Stockport	39	7-19	5.1	3.4	.01	295	50	250	0	1230	30	35	-	-	-	-	-	
McConnelsville	49	7-19	6.8	4.0	.76	370	60	395	0	840	50	50	-	-	-	-	-	
McConnelsville	a 50	8-8	1.4	.50	.55	810	35	150	5	170	15	25	-	-	11.39	7.3	28	
Gaysport	61	7-19	7.2	3.9	.65	270	170	740	0	945	95	261	-	-	-	-	-	
Duncan Falls	67	5-7	.14	.13	00	66	15	6	0	560	0	0	9.1	1.94	9.79	7.5	16	38
Duncan Falls	67	7-19	10.1	4.6	3.0	445	215	680	0	735	105	45	-	-	-	-	-	
Duncan Falls	67	8-9	2.5	1.1	.41	380	25	375	15	445	55	20	-	-	-	-	27	
Zanesville	70	5-7	.45	.44	00	176	4	4	0	1452	0	0	3.6	2.15	9.84	7.4	15.5	
Zanesville	b 70	6-7	1.9	1.8	00	170	24	24	0	3808	8	8	-	-	-	-	15.5	
Zanesville	75	7-17	9.8	3.8	.66	590	115	790	5	440	60	25	-	-	-	-	-	
Zanesville	b 70	7-19	5.3	1.3	1.2	845	115	795	10	765	70	30	-	-	-	7.5	14.5	
Dam #11	84	5-9	1.7	1.6	00	212	0	24	0	600	4	0	4.3	1.75	8.31	7.5	14.5	
Dresden	a 91	4-30	.25	.15	19	105	0	5	0	10	5	0	3.6	0.82	9.88	7.6	15.5	
Dresden	b 91	4-30	1.0	.94	00	165	0	20	0	15	0	0	36	2.79	9.78	7.6	15	115
Coshocton	b 110	5-8	.28	.23	00	232	4	16	0	72	0	4	-	1.72	8.55	7.5	15.5	32
TRIBUTARIES TUSCARAWAS RIVER																		
Coshocton	a 115	5-8	.17	.10	00	124	8	16	4	8	4	0	-	-	-	-	17.5	
W.Lafayette	a 120	5-8	.03	.01	00	36	4	8	0	4	0	0	46	2.29	8.41	7.4	18.5	
Newcomerstown	b 125	5-18	.14	.4	0	276	4	12	0	220	12	0	93	1.43	8.88	7.4	18.5	
Newcomerstown	a 135	5-10	.23	.2	00	240	12	12	0	28	4	0	24	1.17	8.39	7.2	18.5	
New Phila.	b 160	5-23	6.4	6.1	.20	44	4	20	4	3144	20	0	240	1.81	8.90	7.5	19.5	
Dover	a 170	5-23	4.6	4.5	.05	278	8	16	0	2500	32	0	93	2.00	9.26	7.8	19	
Barberton	a 225	5-22	1.2	.70	.07	968	52	272	8	368	76	16	1100	7.29	5.75	6.4	22	
Jonathon Creek		6-10	.30	.16	.10	4	4	40	0	556	8	0	-	-	-	7.7	26	
Mohican River		7-19	5.4	2.4	1.08	8	0	1200	80	130	226	68	-	-	-	7.9	27	
Killbuck River 5 mi.above mouth		7-19	1.8	.94	.77	0	70	10	5	195	85	0	-	-	-	-	-	
LICKING RIVER																		
Newark	b	5-1	.20	.19	00	4	0	16		160	0	0	240	3.20	8.34	7.6	15	
Newark	a	5-2	1.1	.07	00	55	15	15		255	5	0	4.3	2.78	9.40	7.7	10.5	
Utica	b	4-30	.31	.26	00	4	0	0		52	0	4	430	1.73	9.65	7.7	15	
Utica 1.5 mi. above		4-30	2.5	2.5	00	15	0	0		100	0	0	9.3	1.20	9.80	7.8	14.5	
Utica at		4-30	.29	.24	00	36	8	12		48	0	0	15	1.40	9.5	7.8	14.5	
LICKING RIVER TRIBUTARY RACCOON CREEK																		
Johnson	a	4-30	1.9	1.9	00	0		0		64	0	0	9.3	1.23	9.36	7.7	13	
Johnson	b	4-30	1.0	1.0	00	0		8		92	0	0	3.6	1.18	9.68	7.7	13.5	
Granville	a	4-30	1.25	1.2	.05	0		0		60	4	0	4.3	1.15	8.55	7.6	14	
Granville	b	4-30	.66	.66	00	16		0		72	0	0	150	2.65	9.49	7.7	13	

Station Key: a - above; b - below

TABLE 12
HOCKING RIVER

Station		Mile	Date 1940	Volume			Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro	B. coli	BOD.	D.C.	pH	Temp.
				T	I	II												
Hockingport		0.1	6-27	.48	.14	.10	30	110	55	0	50	20	5	7.3	0.27	7.83	7.2	22
"		0.1	7-11	4.9	.81	.44	385	5	958	5	250	50	10	0	2.06	9.15	7.4	26.5
"		0.1	8-14	6.2	1.3	1.9	18	12	171	1015	561	48	61	9.3	1.83	7.21	7.7	28
Coolville		5	8-17	.71	.28	.11	102	12	262	89	87	18	6	-	-	8.41	8.0	28
Guysville		20	8-17	3.6	1.5	1.6	150	6	139	24	90	281	0	-	-	9.0	7.9	27.5
Athens	b	36	6-20	2.1	1.1	.37	25	0	140	15	105	65	0	-	-	5.91	7.6	25
Sunday Creek	b	42	8-17	.62	.26	.06	97	200	137	6	18	12	6	-	-	7.22	7.1	27
Nelsonville	b	50	8-16	3.3	.69	1.9	35	666	132	0	24	244	31	-	-	10.04	8.0	26
Nelsonville		50	7-26	.03	.01	.02	28	0	0	2	2	6	0	-	-	7.35	7.4	27
Logan	a	70	7-26	2.6	2.5	.02	0	0	5	10	420	20	0	-	-	7.21	7.5	27

TRIBUTARIES

Station		Mile	Date 1940	T	I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro	B. coli	BOD.	D.C.	pH	Temp.
Federal Creek		18	6-10	.60	.53	.07	0	0	0	0	104	12	0	-	-	-	7.5	24
Sunday Creek		43	8-16	.02	.02	00	0	0	6	0	6	0	0	-	-	-	3.0	23.5
" "		43	7-23	.91	.83	00	0	10	3	0	15	0	0	-	-	6.60	3.1	27.5
" "		43	7-25	00	00	00	5	0	5	0	0	0	0	-	-		6.0	
Monday Creek		49	8-16	.09	.09	00	0	0	0	0	30	0	0	-	-	7.07	3.2	27
" "							0	0	0	0		0	0	-	-	-	-	-
" "			7-25	.05	.05	00	0	0	5	0	15	0	0	-	-	-	3.8	-
" "		50	7-23	.09	.09		0	0	0	0	30	0	0	-	-	-	2.8	-
" "		50	7-25	.36	.36	00	0	0	0	0	120	0	0	-	-	-	3.3	-
Little Monday Creek		75	6-6	.09	.09	00	0	5	0	0	85	0	0	-	-	-	6.8	26

Station key: a = above, b = below

TABLE 13

LITTLE KANAWHA RIVER

Station		Mile	Date	T	Volume		Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B.coli	BOD.	D.O.	pH	Temp.
			1940		I	II												
Viscose	b	2	8-22	4.6	00	.34	30	0	90	0	0	170	5	-	-	0.33	6.3	26
Viscose	b	2	8-23	2.5	00	.15	0	0	55	0	0	60	0	-	-	0.00	6.1	25
Dam #1	b	3.4	8-23	31.0	00	.01	10	0	710	0	0	125	20	-	-	2.45	6.3	26.5
Dam #1	b	3.4	8-22	13.6	.02	.20	0	0	280	0	5	55	35	2.3	1.50	4.45	6.1	24.5
Dam #1	a	3.5	8-22	19.4	00	00	5	0	450	0	0	25	75	-	-	-	7.2	25
Dam #1	a	3.5	8-23	1.1	00	.04	0	0	45	0	35	20	5	-	-	4.62	7.1	24
Dk 282		5	6-27	.11	.02	00	5	0	15	0	10	5	5	-	-	-	-	22
Hughes Creek		17	8-22	.31	.06	.04	420	0	125	0	10	25	115	-	-	6.40	7.2	23
Elizabeth		25	6-22	1.03	1.03	00	0	0	8	0	26	0	0	-	-	-	-	22.5
Elizabeth	b	26	8-22	1.6	1.2	.15	50	0	95	0	75	260	160	3.6	1.44	7.40	7.2	26
Creston		48	8-21	.75	00	.44	35	0	170	15	5	30	15	-	-	8.20	7.5	26
Grantsville	a	80	8-21	.90	.52	.11	10	0	35	0	10	10	10	-	-	8.80	7.5	26
Grantsville	a	80	8-21	.24	.01	.17	80	0	35	0	0	10	25	-	-	7.50	7.4	24
Glenville	b	101	8-20	1.6	.99	00	165	0	90	10	60	30	0	-	-	6.95	7.1	25
Glenville	a	103	8-20	1.1	.54	00	155	0	40	5	20	10	10	-	-	6.90	7.1	25

Station key: a - above, b - below

TABLE 14
WABASH RIVER

Station		Mile	Date		Volume		Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
			1940	T	I	II													
New Harmony	b	40	9-18	2.3	.61	.71	65	0	250	1920	50	30	60	-	-	9.0	-	8.3	26
" "		52	9-4	1.8	1.0	00	110	5	125	1785	10	10	75	5.4	5.12	6.90	10	8.1	25
Grayville		65	9-18	1.7	.01	.40	55	0	465	985	15	30	45	-	-	9.10	-	8.2	24
Mt. Carmel		92	9-18	.8	.03	00	25	0	300	75	50	10	5	-	-	7.05	-	8.1	-
Patton		102	9-17	2.3	1.0	.01	65	0	600	840	15	10	15	-	-	10.10	-	8.5	25
St.Francisville		115	9-17	1.15	.06	.01	130	10	465	435	15	0	55	320	6.20	8.75	20	8.3	24
Vincennes		127	9-4	1.9	.29	00	45	0	715	525	105	0	5	-	-	-	-	-	-
Moron Ferry		165	9-13	4.1	.08	.18	50	0	1995	765	235	15	20	-	-	10.90	-	8.1	22.5
" "		165	9-27	0.9	.16	00	6	0	863	92	56	12	0	15	3.58	7.55	5	7.9	17
Hutsonville Ferry		172	9-27	1.5	.04	00	140	0	871	110	12	18	12	15	3.50	7.44	4	7.9	17
Darwin Ferry		190	8-12	4.9	2.8	00	6	6	1229	137	124	6	6	460	5.80	4.79	5	7.8	27
" "		190	9-27	2.0	.09	.67	237	0	1335	136	25	6	12	580	3.92	3.91	5	7.7	18
Prairieton		205	9-13	1.6	.24	00	20	0	655	80	85	10	20	-	-	3.40	-	7.7	21.5
Terre Haute	b	210	9-13	2.7	.29	00	25	0	1080	260	135	0	0	-	-	3.50	-	7.7	19
" "	b	210	9-26	2.5	.01	1.5	165	0	426	104	0	36	18	96,000	10.6	1.45	10	7.6	16.5
" "	a	220	9-12	3.3	1.3	.06	56	0	860	225	105	15	5	-	-	9.60	-	8.1	19.5
Clinton	a	232	9-25	1.95	1.1	.01	468	43	666	230	436	18	35	7.5	2.86	8.82	15	8.1	17
Hillsdale		238	8-31	14.7	7.2	00	99	118	2475	48	1117	12	56	-	-	-	-	-	23.5
Montezuma		240	9-12	2.6	1.1	.16	40	5	645	145	175	5	0	-	-	8.00	-	7.9	19
Perrysville		264	8-30	5.6	1.5	.01	99	56	1614	61	505	6	67	-	-	-	-	-	25
"		264	9-25	3.2	.38	1.9	865	31	1026	87	130	30	16	23	3.10	8.60	15	8.2	15.5
Covington		269	9-10	1.6	.56	.45	50	0	240	140	240	35	15	-	-	6.90	-	7.7	21
"		269	10-2	0.6	.40	00	300	31	450	12	111	0	24	13	2.79	10.25	40	8.1	14.5
"	a	270	10-2	0.7	.49	00	448	18	729	6	143	0	6	13	3.09	10.26	40	8.1	14.5
Williamsport		287	10-2	0.6	.47	00	398	18	324	0	212	12	0	195	4.02	10.78	23	8.1	16
Attica		288	8-29	11.1	2.5	.01	43	111	2505	149	374	180	62	-	-	-	-	-	-
"	a	289	10-2	2.4	1.9	.10	178	0	714	6	684	18	12	122	3.50	12.12	12	8.2	17
Independence		294	10-2	4.6	3.35	.07	143	25	1003	18	160	49	30	1100	2.76	11.90	12	8.2	18
Lafayette	b	302	10-3	0.9	.51	00	217	0	572	6	160	24	12	670	3.48	9.25	17	8.1	17
Lafayette		312	8-29	3.65	1.6	.10	101	6	1031	67	493	54	36	-	-	-	-	-	25
Lafayette	a	320	8-29	2.6	1.3	.38	43	18	470	93	506	68	0	-	-	-	-	-	24.5
Delphi	b	330	10-1	4.1	3.1	00	710	56	798	6	179	49	6	43	4.64	14.30	50	8.4	18.5
"		331	9-6	58.3	49.1	4.1	30	483	1819	31	1323	148	61	-	-	9.60	-	8.2	27
"		331	10-1	1.7	.85	.06	886	56	579	0	193	61	61	9.1	4.61	11.37	60	8.4	17.5
Pittsburg		332	8-28	12.3	7.95	1.4	65	78	1417	136	2122	143	60	-	-	-	-	-	-
Georgetown		347	10-3	7.9	4.75	1.1	810	31	958	12	1235	135	66	43	3.95	8.45	45	8.1	16
Logansport	b	353	9-4	11.6	10.3	.69	430	0	295	55	2590	65	0	-	-	14.50	-	8.2	25
"	b	353	9-30	1.6	1.1	.41	265	50	49	0	275	60	0	93	2.92	11.76	15	8.[illegible]	17.5
"		355	9-4	12.3	11.4	.43	1390	0	195	5	458	70	0	-	-	10.50	-	8.2	26
"		356	8-27	2.35	.05	.19	50	60	813	155	90	35	15	-	-	11.50	-	8.2	20.5
"	a	357	9-4	2.6	.36	.49	435	0	850	140	270	75	0	-	-	11.40	-	8.2	25
"	a	357	9-30	5.4	2.1	1.2	692	81	643	67	596	192	80	3.6	8.80	13.30	100	8.4	16.5
Peru	b	370	8-1	14.55	13.25	.43	12	0	332	6	3478	96	6	43	3.41	6.98	90	8.1	24.5
"	b	370	8-27	10.9	5.7	2.5	94	264	1053	43	1781	318	31	-	-	-	-	-	-
"	b	370	9-3	2.9	.11	.35	360	0	1305	180	300	65	10	-	-	-	-	-	-
"	a	375	8-1	18.5	16.55	1.1	0	0	322	25	4161	260	6	7.3	3.32	5.50	150	7.9	23.5
"	a	375	9-3	3.6	.24	1.6	125	0	740	170	130	185	20	-	-	12.00		8.2	25
Wabash	b	386	8-2	28.8	24.5	2.85	50	43	560	80	6257	286	55	930	6.27	6.30	45	7.7	23.5
"	a	390	8-2	14.6	9.1	1.7	6	8	927	62	2466	153	49	.91	3.10	6.35	85	8.0	23.5

Station key: a - above; b - below

TABLE 14, cont.
TRIBUTARIES
TIPPECANOE RIVER

Station		Mile	Date 1940	Volume T	I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	E. coli	BOD.	D.C.	Tby.	pH	Temp.
Springboro		8	9-6	.66	.27	.00	0	0	179	0	281	0	7	-	-	9.50	-	8.2	26
"		8	8-28	1.8	.34	.47	0	48	350	210	230	30	5			-		-	
		8	9-7	.58	.15	.05	20	0	110	10	275	14	5			9.25		8.2	25
Monticello		24	8-30	5.80	.56	2.6	87	181	460	205	659	347	-	-	-	-	-		23.5
Buffalo		38	8-28	1.4	.45	.04	12	43	232	6	156	6	0	-	-	-	-	-	
"		38	9-7	.59	.06	.02	15	0	175	5	35	10	0	-	-	7.20	-	8.1	24.5
Pulaski		48	8-28	.97	.39	.03	40	48	210	0	130	20	0	-	-	-	-	-	-
LITTLE WABASH RIVER																			
Emma		25	9-16	5.9	.13	.4	884	0	215	70	35	320	75	-	-	12.45	-	8.3	23
Carmi	b	41	9-4	.91	.56	.12	64	0	12	4	248	16	64	-	-	-	-	-	22
"	at	42	9-18	1.2	.09	1.0	35	5	30	5	30	0	5	-	-	10.15	-	8.3	27
"	a	43	9-4	11.1	.12	1.0	150	0	3000	6	50	160	75	-	-	-	-	-	22
VERMILION RIVER																			
Grape Creek		19	8-30	3.6	1.6	13	199	111	227	37	941	123	80						22
Danville Below sewage		19	9-11	6.6	1.4	4.5	90	0	240	35	480	420	0	-	-	1.87	-	7.8	21
"	b	19	9-10	9.0	1.9	6.4	40	0	290	30	725	565	15	-	-	2.05	-	7.7	22.5
"		22	8-30	1.4	.63	.20	100	249	204	12	225	90	12	-	-	-	-	-	23.5
"		22	9-11	-	-	-	-	-	-	-	-		-	-	-	9.10	-	-	25
"	a	20	9-11	4.9	1.1	3.3	120	0	135	0	480	340	0	-	-	3.50	-	7.5	23
"	b	14	9-10	3.0	1.3	.49	35	0	305	35	560	100	0	-	-	5.45	-	7.7	20.5
Middle Fork		74	8-30	1.4	.7	.09	154	181	311	0	0	24	6						24
WHITE RIVER																			
Above mouth		3	9-17	1.6	.27	.44	250	5	195	25	85	45	20	2.3	3.95	8.22	-	8.2	24
" "		2	9-5	4.4	3.0	.49	265	50	339	159	110	97	49	8.9	3.85	8.05	25	8.1	25
Hazelton	b	15	9-20	1.4	.58	.21	785	0	210	100	15	55	15	-	-	9.00	-	8.2	26
"	b	15	9-4	4.3	1.4	2.0	204	0	380	124	124	52	36	-	-	-	-	-	23.5
Petersburg	b	47	9-21	1.2	.20	.11	720	5	475	35	70	50	40	-	-	8.50	-	8.1	27
Washington	b	61	9-23	5.6	.94	4.0	965	10	300	50	150	40	125	-	-	6.90	-	8.0	26
Edwardsport		94	9-23	6.6	2.6	2.7	20	65	535	25	3160	45	80	-	-	-	-	-	-
Newberry		116	9-23	12.4	10.2	.34	80	0	847	5	2570	50	10	-	-	11.30	-	8.4	25
Worthington		143	9-24	30.4	28.5	.15	26	37	661	31	6087	30	49	43	7.52	7.98	15	7.9	23
Spencer	b	165	9-24	28.8	24.3	2.3	105	75	1280	61	6112	48	61	93	6.76	11.70	15	8.1	23.5
"		168	9-23	34.5	32.6	.37	5	210	890	15	1618	40	50	-	-	15.65	-	8.3	24
"	a	170	9-24	44.3	38.1	1.6	43	289	3128	61	9540	67	48	15	5.72	9.40	15	8.1	23
Martinsville	at	194	9-3	7.6	2.9	.91	18	118	1997	211	3600	130	0	-	-	8.60	-	8.2	23.5
"	b	190	9-10	5.0	2.7	.16	6	93	1244	0	4562	18	24	460	5.28	9.72	7	8.2	21.5
"		194	9-10	4.2	1.6	.50	6	93	951	42	2096	42	18	2400	5.77	9.90	-	8.1	21.5
"	a	200	9-10	2.7	1.5	.49	0	69	686	12	1437	24	12	2.3	4.46	10.05	7	8.2	21

Station key: a - above b - below

TABLE 14, cont.

TRIBUTARIES

Station		Mile	Date 1940	T	Volume I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
White River, cont.																			
Indianapolis	b	225	9-17	2.0	1.6	.10	6	20	222	0	560	12	0	7.3	7.31	4.45	3	7.7	21
"	b	237	9-17	1.1	.55	.15	0	37	481	0	477	84	0	23	8.33	6.02	8	7.7	24.5
"	b	239	9-17	9.4	1.2	.96	237	493	1634	12	1042	102	18	230	8.29	6.30	-	7.7	25
"	a	257	9-17	11.6	2.8	3.5	206	530	3014	6	16575	215	56	9.3	5.02	12.04	35	8.1	17.5
Noblesville	b	265	9-27	4.4	1.7	.91	54	796	1539	0	6942	27	16	-	-	8.50	-	8.1	15
"	b	265	9-12	35.7	1.8	31.1	400	1740	665	0	1425	1062	115	4.60	7.97	8.59	-	8.1	19
"	a	271	9-12	21.1	1.6	17.8	135	1496	1093	0	1145	1136	24	23	5.70	11.61	23	8.4	18.5
Anderson		297	8-21	4.1	3.0	.1	14	55	294	0	4882	42	6	390	3.99	5.30	55	8.0	21.5
Muncie	b	309	8-21	3.4	.36	1.7	0	0	1667	0	120	136	24	460,000	22.8	0.00	-	7.1	17.5
"	b	310	8-21	.08	.02	00	6	0	200	0	6	0	0	1100,000	59.6	0.00	70	6.1	19.5
"	a	312	8-21	3.5	1.3	1.4	50	81	334	0	49	259	49	46	2.22	9.04	65	8.2	21
Winchester	b	338	8-22	5.5	1.4	3.2	62	305	485	0	80	279	68	46,000	8.25	2.87	17	8.0	19
EAST FORK OF WHITE RIVER																			
Above mouth		51	9-21	.48	.11	.10	160	0	90	70	80	35	10	-	-	7.75	-	8.2	24
Shoals		75	9-3	.74	.05	00	40	5	135	40	5	45	60	.91	-	-	-	-	16
Bedford		93	9-3	.75	.19	00	260	5	400	70	55	5	10	-	-	-	-	-	-
EEL RIVER (White River)																			
Worthington			9-23	.63	.12	.18	1730	0	175	45	10	145	20	-	-	8.45	-	8.1	26
PATOKA RIVER																			
Above mouth			9-17	-	-	-	-	-	-	-	-	-	-	-	-	8.45	-	5.0	21
Below Princeton waterworks			9-20	2.5	.57	.17	40	0	805	100	360	65	0	-	-	9.20	-	6.9	23
Above "			9-20	.23	.04	.17	555	0	0	0	0	105	5	-	-	9.20	-	6.9	23
OTHER TRIBUTARIES																			
WILD CAT CREEK near mouth			8-29	3.9	2.4	.61	286	31	358	53	380	151	25	-	-	10.50	-	8.2	24.5
			9-6	2.6	.64	.32	225	0	810	150	50	10	20	-	-	10.85	-	8.6	25
EEL RIVER Spencer Park			9-4	11.6	10.7	.19	310	0	180	5	2680	30	30	-	-	10.49	-	8.2	24
EMBARRASS RIVER Lawrenceville			8-31	23.8	20.4	2.1	157	75	337	0	2198	450	27	-	-	8.70	-	8.1	19
"	a		9-26	5.9	5.0	.70	145	0	15	5	90	95	20	-	-	8.70	-	8.1	19
"	b		9-26	.89	.01	.82	100	0	95	0	30	180	5			8.95	-	8.2	25
MISSISINEWA RIVER mouth			9-3	.48	.08	.39	305	0	5	5	0	40	0	-	-	9.25	-	8.2	23

Station key: a - above; b - below

TABLE 15
TRADEWATER RIVER

Station	Mile	Date	Volume			Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Fro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
			T	I	II													
Providence		10-4	.11	.02	.02	62	0	6	0	12	12	6	-	-	9.00		7.7	17
Sturgis		10-4	.17	.03	.07	31	6	0	0	6	37	12	-	-	5.90		7.5	18
SALINE RIVER																		
Gibsonia		10-3	1.3	.74	.02	35	20	10	0	150	85	30			5.85		7.5	19
GREEN RIVER																		
Below Dam 1	9	10-8	.02	.02	00	38	0	0	0	69	0	0	.91	0.43	8.40	13	7.7	21
Ky. Hwy. 54	25	10-8	.03	.03	00	6	0	6	0	144	0	0	-	-	7.05	-	7.7	22
Ky. Hwy. 56	45	10-7	.07	.06	00	25	0	0	0	280	6	0	-	-	6.70	-	7.8	21
Above Dam 2	64	10-7	.09	.09	00	6	0	0	0	425	0	0	-	-	6.50	-	7.6	21
Below Rough River	70	10-9	.28	.16	.10	106	0	0	0	44	18	0	-	-	7.35	-	7.6	22
Above Rough River	72	10-9	.05	.04	00	6	0	0	0	310	0	12	-	-	7.10	-	7.6	22
Dam 3	108	10-24	.04	.02	00	25	15	10	0	30	0	0	-	-	8.68	-	7.8	19.5
Dam 4	149	10-22	1.6	.00	.50	25	0	12	0	0	12	49	-	-	9.15	-	7.7	18
Mouth of Barren R.	150	10-24	.05	.01	00	10	10	10	0	10	0	10	-	-	-	-	-	19
Dam 6 below	180	10-18	.15	.14	00	645	0	5	0	10	5	5	-	1.22	9.45	-	7.8	17
Dam 6 above	182	10-18	.03	.03	00	234	0	0	0	0	0	2	.23	1.22	8.33	5	7.8	17
Munfordville	212	10-17	.02	.01	00	57	0	0	0	38	0	6	.75	0.78	9.90	8	7.7	14
Greensburg	260	10-16	.02	.02	00	18	0	0	0	62	0	0	-	-	8.31	-	7.6	15
Eunice	310	10-16	.27	.01	00	181	0	6	0	6	75	6	-	-	8.78	-	7.4	17
TRIBUTARIES																		
Nolin River	82	10-14	.19	.01	.17	6	0	0	0	44	24	0	-	-	-	-	7.9	18.5
" "	34	10-11	.51	.51	00	75	0	0	0	5	5	0	4.3	1.14	9.95	-	7.9	16
" "	83	10-14	.02	.01	00	81	0	0	0	0	6	0	-	-	8.85	10	7.9	18.5
Barren River	15	10-22	.23	.02	.05	45	3	6	0	15	6	0	.91	1.08	8.33	10	7.7	17
" "	60	10-19	.00	.00	00	10	0	0	0	20	0	0	2.3	1.81	6.78	10	7.7	16
" "	75	9-29	.04	.04	00	25	0	6	0	144	0	0	-	-	-	-	-	-
" "	90	10-19	.02	.02	00	206	6	0	0	6	-	0	2.3	0.10	8.90	-	7.7	14.5
Mud River	34	10-24	.67	.58	00	15	80	35	0	5	0	5	-	1.20	2.64	-	7.3	14
Rough River	1	10-9	.09	.01	00	69	0	6	0	50	12	25	-	-	7.20	-	7.6	21
" "	30	10-9	.06	.00	.04	50	0	0	0	0	24	0	-	-	6.10	-	7.1	17
" "	80	10-11	.31	.04	.19	301	0	12	0	6	42	6	-	-	6.15	-	7.5	16
" "	120	10-11	.03	.02	00	63	0	0	0	12	0	12	-	-	8.70	-	7.8	14
Pond River	15	10-5	.97	.10	.72	1383	0	0	0	5	130	15	-	-	8.25	8	7.2	16.5
" "	25	10-5	1.3	.14	.83	1100	5	10	0	20	234	15	-	-	5.60	8	7.0	16
" "at mouth	0	10-5	.66	.54	.09	55	0	0	0	35	15	15	-	-	-	-	7.7	23

TABLE 16
CUMBERLAND RIVER

Station	Mile	Date 1940	Volume T	I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	D.O.	pH	Temp.
Dam F	43	11-18	.06	.04	00	16	35	5	0	20	0	6	10.97	7.7	11
Dam E	66	11-18	.10	.09	00	5	90	10	0	70	0	20	10.57	7.6	10
Dam D	88	11-15	.12	.08	00	15	90	20	0	0	0	0	10.35	7.6	11
Dam C	108	11-15	.08	.05	00	5	0	10	0	15	0	5	9.35	7.6	11
Dam B	140	11-6	1.0	.01	00	0	0	208	0	4	4	8	8.30	6.5	17
Dam A	150	11-4	4.7	.01	00	0	5	590	0	60	5	35	6.29	7.5	16.5
State Pen.	182	10-30	1.1	.07	00	5	75	265	0	20	5	5	3.21	7.3	20
Dam 1 below	187.5	11-4	.32	.14	00	0	140	50	5	5	15	5	5.99	7.3	19
Dam 1 below	187.5	10-30	.67	.06	.18		36	124	0	64	8	72	1.73	7.3	22
Dam 1 at	188	10-30	.10	.06	00	10	30	10	0	15	0	0	0.67	7.8	21
Below Nashville	189	10-30	8.2	1.1	5.0	40	210	615	0	45	65	660	2.66	7.1	18
Dam 2	201	11-1	.73	.44	00	8	44	112	0	12	28	0	6.10	7.3	18
Below Dam 3	217.5	11-7	.10	.04	00	35	30	50	0	30	0	20	9.30	7.9	16
Dam 3	218	11-1	.19	.03	00	0	24	56	0	8	0	20	9.65	7.9	18
Dam 4	237	11-7	.42	.07	00	10	70	130	5	10	5	0		7.7	16.5
Dam 5	264	11-12	.33	.06	00	25	35	15	5	90	0	0	9.70	7.8	14.5
Dam 6	281	11-13	.04	.02	00	80	35	30	0	5	5	0	10.15	7.7	13.5
Dam 8	317	11-13	.06	.02	00	205	10	10	5	0	0	0	10.05	7.8	14

TRIBUTARIES

Station	Mile	Date 1940	Volume T	I	II	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	D.O.	pH	Temp.
Harpeth River	152	11-4	.07	.05	00	5	0	5	0	15	0	5	8.30	7.7	14.5
Stones River	205	10-29	.72	.10	00	88	76	60	0	8	4	8	8.05	7.7	18
Caney Fork	309	11-13	.13	.10	00	175	5	15	0	40	0	0	10.90	7.7	12

TABLE 17
OHIO RIVER

Station	Mile	Date 1940	Volume Total	Chr.	Cry.	Chl.	Myx.	Pac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
Fmsworth Dam	6.	10-10	0.09	0	0	75	0	0	0	5	.46	0.76	2.85	9	5.8	16.5
" "	6	10-22	0.02	10	0	45	0	0	0	0	.20	1.22	3.07	8	5.3	12.5
	13.5	10-10	0.34	5	0	45	0	60	0	0	15.	0.82	7.95	9	5.9	16.5
	13.5	10-22	0.24	10	0	40	0	120	10	5	11.	1.61	7.53	6	5.3	13.5
Montgomery Dam	31.7	10-10	.13	40	20	90	0	5	0	0	11	1.02	8.07	6	6.2	17.5
" "	31.7	10-22	.08	0	0	105	0	35	0	5	7.3	0.72	8.21	7	5.2	14.0
Dam No. 7	36.5	10-10	.16	25	0	125	0	0	5	0	11	1.23	10.10	7	6.4	17.5
" " "	36.5	10-22	.38	5	0	85	0	0	5	0	24	0.85	10.16	8	5.3	14.0
Dam No. 8	46.4	10-11	.11	20	0	70	0	0	5	0	4.6	0.65	9.59	3	6.0	17.0
" " "	46.4	10-21	.24	25	0	30	0	75	5	5	161	1.06	9.79	7	5.6	13.5
Dam No. 9	56.1	10-11	.30	0	0	205	0	5	10	0	0	0.63	9.46	3	5.9	16.0
" " "	56.1	10-21	.43	10	0	40	0	10	5	0	46	1.17	9.71	6	5.6	13.0
Dam No. 10	66	10-11	.77	0	0	160	0	15	0	10	.1	0.84	9.22	3	4.7	17.5
" " "	66	10-21	.50	265	0	68	0	40	5	0	59	1.59	9.65	8	5.4	14.5
Dam No. 11	77	10-11	.36	0	0	200	0	10	0	0	4.6	1.39	7.72	3	4.7	17.5
" " "	77	10-21	.27	155	45	40	0	0	5	0	4.3	2.25	8.39	7	5.2	13.5
Dam No. 12	87.5	10-11	.09	0	0	210	0	0	0	0	.4	1.22	8.10	4	4.7	16.5
" " "	87.5	10-21	.03	60	0	70	0	0	0	0	4.6	1.36	8.40	10	5.0	12.5
Dam No. 13	96	10-11	.07	5	0	960	0	0	0	0	2.4	1.80	8.70	4	4.7	16.5
" " "	96	10-21	.42	0	0	220	10	25	0	0	4.6	1.07	9.26	6	4.9	12.5
Dam No. 14	114	6-28	.39	30	0	130	0	135	0	0	4.6	0.90	8.43	20	7.3	22.5
" " "	114	7-10	.55	50	0	100	0	50	0	10	46	0.63	8.82	10	6.6	24.
" " "	114	7-16	.39	120	0	140	0	0	0	0	15	0.47	8.49	8	6.7	21
" " "	114	7-30	.40	135	0	110	0	20	0	20	24	1.04	7.68	9	6.4	28.
" " "	114	8-27	1.80	0	0	1760	0	10	0	0	.4	1.19	7.89	4	4.1	24.
	114	9-10	.23	0	0	250	0	5	0	5	.2	0.74	7.32	5	4.3	21.
Dam No. 15	129	6-28	.34	5	0	65	0	10	5	5	23	0.71	8.38	17	7.2	22.
" " "	129	6-30	.23	85	0	55	0	85	5	0	-	-	-	-	-	28.
" " "	129	7-10	.83	5	0	55	0	25	0	5	9.3	0.57	9.21	9	6.6	24.
" " "	129	8-15	.07	0	0	85	0	0	0	0	11	0.84	6.98	4	4.9	25.
" " "	129	8-27	00	5	0	0	0	0	0	0	.9	0.88	7.65	4	4.2	23.
	129	9-10	.10	0	0	75	0	5	5	0	.4	0.40	7.89	6	4.3	22.5
Dam No. 16	146.5	6-28	.25	10	0	30	0	20	10	0	35	0.68	8.31	70	7.1	22.0
" " "	146.5	7-10	.10	35	0	200	0	65	5	0	2.3	0.70	9.29	9	6.7	23.0
" " "	146.5	7-16	.33	355	0	160	0	15	0	0	24	0.82	9.04	8	6.8	23.5
" " "	146.5	7-30	.23	30	0	105	0	28	0	0	4.3	0.82	7.73	11	6.4	28.5
" " "	146.5	8-27	.72	0	0	20	0	10	0	0	2.3	1.61	8.03	3	4.6	23.0
	146.5	9-10	.20	0	0	235	0	0	0	0	.4	1.16	9.12	5	4.4	22.0

TABLE 17, cont.
OHIO RIVER

Station	Mile	Date 1940	Volume Total	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
Dam No. 17	167.5	6-28	.32	10	0	60	0	30	0	5	240	0.90	8.31	27	7.0	22.5
" " "	167.5	7-10	1.20	100	0	100	0	95	10	0	0	1.11	9.15	11	7.0	23.0
" " "	167.5	7-16	.77	480	0	105	0	70	10	5	4.3	1.10	8.87	10	7.0	23.5
" " "	167.5	7-30	.35	230	0	290	0	20	0	5	9.3	1.32	7.87	11	6.7	29.0
" " "	167.5	8-15	.20	0	0	90		90	0	5	.9	1.45	6.85	4	6.0	27.5
" " "	167.5	8-27	1.40	5	0	10	0	15	0	10	2.3	0.72	8.63	2	4.8	24.0
" " "	167.5	9-10	.33	0	0	390	0	0	0	0	.2	0.70	9.12	7	4.9	23.0
Dam No. 18	180	6-27	1.3	50	10	150	5	160	20	25	15	1.38	8.59	70	7.1	22.0
" " "	180	7-11	1.9	125	10	230	30	70	75	5	75	1.26	9.09	16	7.0	24.5
" " "	180	7-17	4.0	480	20	225	30	395	19	20	2.3	1.32	8.62	10	7.3	24.0
" " "	180	7-29	1.7	100	0	95	10	395	20	20	23	1.77	7.36	18	7.3	29.5
" " "	180	8-14	1.2	15	0	50	0	185	0	10	9.3	1.25	7.36	3	7.4	28.0
" " "	180	8-28	.40	110	0	55	0	55	15	5	240	3.11	7.47	345	6.9	23.5
" " "	180	9-9	.89	45	0	845	15	240	5	5	24	1.25	8.39	14	6.3	23.5
Dam No. 19	192	6-27	.61	5	0	100	0	20	15	10	91	1.58	8.46	59	7.3	23.0
" " "	192	7-11	3.5	80	0	215	20	305	10	0	9.3	1.22	8.89	14	6.9	23.0
" " "	192	7-17	2.3	375	0	70	0	60	0	20	24	5.43	8.43	8	7.5	24.0
" " "	192	7-29	1.2	80	0	65	0	255	5	20	93	1.57	7.61	40	7.3	30.0
" " "	192	8-14	.86	25	20	65	0	360	10	15	46	1.26	7.11	5	7.5	28.5
" " "	192	8-26	.97	10	0	25	0	75	0	5	21	1.13	7.52	4	7.1	23.5
" " "	192	9-9	.67	30	0	590	35	295	5	10	93	1.50	8.10	14	6.8	23.5
Dam No. 20	202.5	6-27	1.6	16	0	204	24	112	24	8	43	1.36	8.30	48	7.3	23.0
" " "	202.5	7-11	3.7	105	0	305	0	280	10	0	121	1.05	8.92	16	6.9	24.0
" " "	202.5	7-17	2.9	252	15	60	5	170	15	15	110	1.41	8.56	12	7.2	23.5
" " "	202.5	7-29	.60	25	10	115	5	375	0	10	93	1.77	7.51	49	7.2	29.0
" " "	202.5	8-26	.67	0	0	45	0	185	0	0	2.3	1.05	7.72	4	7.1	24.0
" " "	202.5	9-9	.16	15	0	25	0	185	0	0	11	1.78	8.60	12	6.8	23.5
Dam No. 21	214.5	6-27	.78	15	5	190	0	60	15	0	75	1.51	8.33	48	7.2	22.
" " "	214.5	7-11	1.0	50	0	135	0	185	0	0	46	1.15	9.02	17	6.9	24.
" " "	214.5	7-17	2.6	630	5	35	5	277	15	0	15	1.25	8.43	12	7.2	23.
" " "	214.5	8-14	1.5	5	0	185	0	255	0	5	.9	1.15	7.75	4	7.4	27.5
" " "	214.5	8-26	.83	10	0	15	0	250	0	0	15	1.31	8.03	3	7.1	25.
" " "	214.5	9-9	.24	5	0	35	0	160	10	0	24	1.10	8.73	12	6.8	23.
Dam No. 22	221	6-27	.48	10	16	239	0	26	5	0	110	1.45	8.12	84	7.2	23.
" " "	221	7-11	2.40	10	0	10	10	115	0	0	15	1.21	8.79	15	6.7	23.
" " "	221	7-17	1.00	615	4	28	0	128	9	4	15	0.96	8.40	13	7.0	21.5
" " "	221	7-29	.33	65	0	40	0	100	0	5	15	1.22	7.12	77	7.1	27.
" " "	221	8-14	1.3	0	0	165	5	335	0	0	.7	1.18	7.82	5	7.4	27.
" " "	221	8-26	.81	20	0	110	0	205	5	0	24	1.11	7.89	3	7.1	23.
" " "	221	9-9	.55	35	0	200	15	445	0	5	2.3	1.00	8.62	13	6.8	22.
Dam No. 23	231.5	6-27	1.2	5	5	145	0	35	20	0	230	1.45	8.26	62	7.2	23.
" " "	231.5	7-11	.06	0	0	5	0	60	0	0	3.9	0.85	8.91	16	6.6	24.
" " "	231.5	7-17	1.10	765	0	50	10	115	15	10	9.3	1.37	8.57	12	7.1	23.5
" " "	231.5	7-29	.56	35	5	50	5	255	5	10	4.3	1.23	7.34	41	7.1	29.
" " "	231.5	8-26	1.40	0	5	115	0	475	0	0	1.5	1.28	8.06	3	7.0	24.5
" " "	231.5	9-9	.72	30	0	125	5	575	5	0	2.3	1.51	9.27	11	6.8	22.5

TABLE 17, cont.
OHIO RIVER

Station	Mile	Date 1939	Volume	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
	316	6-23	2.9	16	0	124	16	3,544	8	16	93	1.32	8.63	65	-	26
		6-29	.19	4	0	16	4	130	0	4	43	1.60	7.32	85	7.3	26
		7-7	.49	4	0	28	0	188	20	4	30	1.33	7.99	-	-	26
		7-13	.59	4	16	96	0	40	0	8	91	0.48	7.70	-	-	26.5
		7-21	.21	0	16	48	0	64	4	0	333	0.95	7.69	-	-	25
		7-27	.42	36	104	64	36	52	8	4	72	0.84	8.27	-	-	26
		8-4	.29	16	0	80	0	72	0	0	59	1.09	7.60	-	-	26
		8-10	.12	304	28	52	20	64	0	16	95	0.76	8.07	-	-	25.5
		8-18	4.9	52	24	66	0	1,684	0	20	515	0.61	7.55	-	-	27.5
		8-24	.37	112	20	36	40	164	4	16	159	0.88	7.90	-	-	26.5
		9-1	.09	8	36	16	20	12	0	16	310	0.90	7.23	6	7.3	26
		9-6	.25	52	48	12	0	4	0	20	264	0.92	7.27	-	-	25
		9-14	.02	4	12	8	0	4	0	0	69	0.70	7.55	-	-	26.5
		9-20	.08	16	20	8	0	0	0	8	142	0.85	7.39	-	-	24
		9-28	.08	16	4	8	0	4	4	4	76	0.92	7.59	-	-	23.5
		10-12	.43	24	4	140	4	168	0	0	387	0.67	8.32	-	-	20
		10-24	.26	0	4	56	0	8	0	0	283	0.61	9.31	-	-	16.5
		11-9	.30	12	24	108	88	140	0	0	121	1.07	11.34	-	-	11
		11-27	.11	36	0	60	12	44	0	0	93	0.81	12.28	-	-	8
		12-15	.05	56	0	24	8	48	0	8	18	0.93	12.29	-	-	6
		12-26	.02	4	0	8	0	32	0	0	33	1.05	12.72	-	-	3.5
Dam 29	320	6-23	2.0	3	0	75	5	1,506	3	9	116	1.41	8.26	95	-	26
		6-29	1.5	27	3	45	0	84	3	3	93	1.57	7.43	90	7.2	26
		7-13	.42	16	4	80	0	20	4	8	240	0.64	7.66	100	7.5	26.5
		7-21	.35	12	8	12	0	16	12	16	523	1.02	7.80	200	7.3	25
		7-27	.60	0	272	76	12	68	12	16	119	1.11	8.23	24	7.2	26.5
		8-10	.47	12	36	100	40	56	4	16	399	.97	8.13	23	7.4	26
		8-18	.67	16	32	84	4	100	8	0	312	0.63	7.62	45	7.6	27.5
		8-22	13.3	52	36	72	8	4,400	4	20	471	1.11	7.54	29	7.4	26
		9-6	.41	92	120	28	4	12	4	45	264	1.14	7.12	9	7.3	25.5
		9-12	.26	32	72	36	32	20	0	24	129	0.86	7.57	2	7.7	25
		9-14	.05	56	16	8	0	8	4	0	82	0.98	7.37	6	7.6	26.5
		9-20	.02	4	0	8	0	36	0	0	81	0.68	7.60	4	7.4	23.5
		9-28	.39	20	108	64	0	12	8	4	76	1.07	7.90	3	7.7	24.0
		10-12	.19	4	0	120	40	56	0	4	125	0.77	8.30	4	7.6	21.0
		11-27	.21	65	4	44	12	36	0	8	48	0.97	12.17	7	7.4	7.5
	330	6-14	.63	99	30	156	0	125	4	30	181	2.42	8.5	23	-	25
		6-20	3.2	60	4	40	0	580	4	0	102	1.16	7.73	27	-	25.5
		6-30	.11	4	0	52	0	28	4	8	240	1.76	6.57	75	7.2	26.5
		7-14	.12	0	0	40	8	8	4	0	69	1.07	7.85	-	-	25.5
		7-20	.51	16	23	28	0	8	0	16	252	1.10	8.05	-	-	26
		7-28	.35	20	28	104	4	32	8	12	387	1.42	7.98	-	-	26
		8-3	1.1	28	0	32	8	64	0	4	150	1.24	7.5	-	-	26
		8-11	.44	240	108	120	40	108	4	4	155	0.88	8.31	-	-	25.5
		8-17	3.8	16	8	32	12	1216	16	0	115	0.54	7.62	-	-	27.5
		8-29	.47	32	44	8	28	164	0	0	76	0.85	7.44	-	-	26
		8-31	.06	8	40	20	0	8	0	4	199	0.81	7.34	-	-	25.5
		9-7	.41	44	96	12	16	0	0	36	106	0.80	7.44	-	-	25.5
		9-15	1.5	12	24	52	8	32	0	0	391	0.73	7.14	-	-	23
		9-21	.06	0	16	0	4	12	0	0	338	0.66	7.30	-	--	23
		9-29	.04	8	36	0	0	8	0	0	337	0.81	7.56	-	-	23.5
		10-13	.08	44	16	48	0	4	0	4	167	0.53	8.46	-	-	20
		10-23	.26	0	8	44	0	24	4	0	177	0.64	9.18	-	-	16
		11-10	.34	8	28	32	4	104	8	4	67	0.91	11.34	-	-	10.5

TABLE 17, cont.
OHIO RIVER

Station	Mile	Date 1939	Volume	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
Dam 29, cont.	337	6-14	1.5	184	44	452	0	320	4	8	93	1.96	7.89	20	-	25
		6-20	.60	66	0	48	0	559	3	0	138	1.36	7.58	32	-	26
		6-30	.09	45	0	41	0	48	0	0	195	1.63	6.80	75	7.2	25.5
		7-14	.71	16	28	152	0	12	8	8	95	1.17	7.55	85	7.5	26.5
		7-20	.40	36	80	52	4	4	0	24	65	1.15	7.68	39	7.2	25.5
		7-28	.76	56	144	108	20	82	4	16	74	1.41	7.96	22	7.3	26.5
		8-3	1.3	36	0	56	8	104	16	12	161	1.29	6.87	85	7.1	26
		8-11	.42	146	260	98	64	56	20	40	157	1.10	7.93	13	7.4	25.5
		8-17	4.5	40	36	84	8	1436	8	8	73	0.86	7.29	45	7.3	27
		8-29	.33	72	36	68	40	76	0	8	27	0.95	7.29	4	7.2	26
		8-31	.10	8	52	28	4	88	0	8	60	0.89	7.02	5	7.2	25.5
		9-15	.06	30	8	16	4	24	0	0	50	0.76	7.30	5	7.5	26
		9-21	.85	0	30	36	0	12	4	8	31	1.01	7.20	7	7.2	23
		9-29	.05	16	4	28	0	68	0	0	52	0.67	7.55	3	7.8	23
		10-13	.03	12	28	0	0	0	0	0	38	1.01	8.51	5	8.0	20
		10-23	.05	0	12	0	8	0	8	16	89	0.97	9.14	4	7.7	16.5
		11-10	.28	36	88	4	0	168	4	0	76	0.72	11.04	7	7.3	10
		11-24	.08	68	28	104	0	24	0	0	31	0.91	11.68	4	7.5	8.5
Dam 33	405	5-1	.32	8	40	32	0	12	0	4	43	1.49	9.80	47	7.5	13
		5-9	37.1	40	184	80	0	5408	4	52	4.3	1.14	9.89	15	7.7	17.5
		7-18	.94	4	0	16	0	4	12	12	9.3	1.99	7.93	53	7.3	25.5
		7-24	.34	4	0	76	0	4	4	8	110	2.41	7.15	170	7.3	26
		8-1	.50	28	0	40	0	140	12	4	75	1.92	7.06	78	7.2	26.5
		8-7	.57	20	16	16	4	284	4	20	9.1	1.33	7.76	27	7.5	27
		8-15	.53	236	0	0	0	80	0	12	24	2.64	7.20	65	7.3	27.5
		8-21	4.8	4	0	12	4	1470	0	4	23	2.14	7.53	46	7.3	27
		8-29	.46	52	0	56	12	228	0	4	4.6	.90	7.60	15	7.9	26
		9-12	.25	0	4	44	40	56	4	0	.23	1.21	7.76	8	7.6	25.5
		10-30	.36	28	8	44	8	296	0	4	43	1.42	8.65	38	7.3	15.5
		11-13	.56	60	56	108	0	304	4	0	2.3	1.39	11.12	7	7.2	9
		11-27	1.2	216	68	270	0	116	4	28	15	1.36	11.70	10	7.3	7.5
Dam 34	434	5-1	.40	8	44	12	0	16	0	12	23	2.92	9.36	51	7.5	13.5
		5-9	26.6	28	164	64	0	2692	0	8	9.3	1.26	10.13	20	7.8	17
		5-17	11.9	50	144	64	0	2032	20	24	4.3	1.26	9.94	8	7.7	18
		5-25	3.0	180	16	68	0	948	0	72	2	2.32	9.13	4	7.6	23
		6-12	.51	20	0	68	0	326	0	4	22	1.22	7.70	13	7.8	24.5
		6-20	.11	81	3	37	5	45	6	0	109	2.17	7.34	108	7.6	26
		6-26	.89	17	3	102	0	987	6	17	36	3.58	8.10	97	7.6	25
		7-18	.82	0	0	63	0	41	27	12	53	1.15	7.81	46	7.4	25
		7-24	.45	0	0	4	8	12	4	12	31	1.65	7.10	190	7.3	25.5
		8-1	.43	35	4	80	4	32	16	4	30	1.37	6.66	125	7.3	25.5
		8-7	.45	12	0	100	12	188	12	0	20	1.23	7.41	23	7.4	26.5
		8-21	1.0	20	0	48	4	456	8	20	264	1.56	7.06	122	7.3	26.5
		8-29	.46	24	0	12	0	356	12	0	1	1.60	8.07	15	7.7	25
		9-12	.08	4	0	44	8	48	0	4	1	0.92	7.90	8	7.6	24.5
		9-18	00	0	0	0	0	0	0	0	1	0.86	7.99	7	-	24.5
		10-2	.05	0	0	20	0	12	0	0	7	0.91	8.38	13	7.5	20
		10-10	.09	8	4	36	0	44	4	0	1	1.05	8.54	11	7.7	21
		10-30	.49	8	0	36	12	196	0	0	9	1.44	8.82	64	7.5	14
		11-13	.62	204	4	128	0	136	4	12	3	.85	11.28	7	7.2	6
		11-27	1.3	326	56	308	8	160	0	4	8	1.08	11.58	12	7.5	9

TABLE 17, cont.
OHIO RIVER

Station	Mile	Date 1939	Volume total	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
Dam 36	461	5-1	.24	16	16	4	0	24	0	4	3.6	1.18	9.43	56	7.7	12
		5-9	32.8	152	172	92	0	2,780	8	8	2.3	1.22	10.27	25	7.8	15
		5-17	18.3	12	44	76	0	4,768	0	92	0.3	1.70	10.00	5	7.8	17
		5-23	38.6	100	52	64	0	3,104	0	92	1	0.88	9.48	6	7.4	21
		6-8	3.8	244	0	184	0	2,452	28	16	4.3	1.84	7.81	29	8.0	24
		6-20	.88	96	0	36	4	180	0	0	150	2.44	7.43	230	7.7	24
		7-18	1.5	12	0	132	0	52	36	8	9.3	1.33	8.03	60	7.3	24
		7-28	.30	4	0	16	0	52	16	8	23	2.15	7.69	64	7.3	25
		8-3	.62	36	16	12	0	88	8	4	30	1.35	6.63	90	7.2	25.5
		8-7	.49	4	0	24	4	24	8	4	43	1.08	7.37	23	7.4	26
		8-21	1.1	40	0	40	4	152	8	36	43	4.95	7.16	39	7.3	25.5
		8-29	.92	16	0	44	0	768	8	4	0.93	1.00	8.65	15	8.0	24
		9-8	.17	4	0	4	4	168	4	0	2.4	1.60	7.68	10	7.5	26
		9-12	.08	4	0	0	28	52	0	0	0.43	1.01	7.84	8	7.6	24.5
		9-18	1.5	0	0	526	0	24	0	0	0.93	0.66	8.68	7	-	24.5
		10-2	.11	0	0	64	4	45	0	0	4.3	0.83	8.30	14	7.5	17.5
		10-12	00	12	0	0	0	0	0	0	0.93	0.55	8.44	6	7.5	18.5
		10-30	.43	148	4	64	8	132	0	0	3.6	1.15	9.48	60	7.5	14.0
		11-13	1.3	424	116	98	4	232	16	24	0.93	1.30	11.68	8	7.3	9
		11-27	2.0	260	4	156	4	140	12	4	3	1.46	12.10	14	7.5	8
Dam 37	483	5-4	1.1	16	88	32	0	112	4	28	240	1.49	8.92	36	7.5	14
		5-12	74.7	8	148	105	0	3,164	16	52	2,400	2.51	9.58	12	7.8	19
		5-18	7.6	4	27	54	0	1,572	12	3	2,150	2.99	8.97	8	7.9	20
		5-22	27.8	156	100	56	0	2,552	8	64	230	4.93	7.35	33	7.6	24
		6-1	3.5	308	0	52	0	1,468	12	4	2,300	4.03	6.93	10	7.6	25
		6-13	.28	24	16	39	6	260	0	3	430	3.46	7.28	132	7.8	23
		6-19	.42	16	0	48	0	240	4	8	300	3.30	6.77	205	9.0	26
		7-17	.60	4	0	42	3	30	36	6	390	2.10	7.40	105	7.2	26
		7-31	.77	9	18	73	24	45	18	15	400	3.15	6.65	160	7.4	27
		8-8	.39	12	0	51	4	132	11	0	24,000	2.64	5.59	50	7.3	27
		8-13	2.3	24	24	76	8	120	36	8	93	1.07	3.70	10	7.3	26
		8-21	.84	20	4	44	20	284	8	32	2,400	2.30	3.03	15	7.2	23
		8-28	1.2	108	0	56	8	994	12	72	313	1.79	6.27	25	7.5	26
		9-5	1.7	12	0	27	0	2,044	8	0	91	3.06	5.19	15	7.8	25
		9-11	.23	12	0	48	0	88	0	0	373	1.11	2.96	10	7.6	26
		9-19	.55	12	0	356	4	136	0	4	240	1.65	5.58	10	7.4	25
		9-25	1.5	16	20	644	8	72	0	118	2,400	2.56	2.22	15	7.3	24
		10-9	.37	0	0	184	4	64	0	4	13,100	1.88	4.68	7	7.5	22
		10-27	.33	64	0	24	0	488	0	0	46,000	1.05	6.54	10	7.5	18
		10-31	.74	128	4	136	8	336	8	4	910	1.85	8.84	45	7.4	13
		11-14	.49	180	0	92	0	272	4	16	230	1.32	11.33	-	7.5	9
		11-30	.20	404	4	120	68	160	0	0	2,340	3.44	11.08	-	-	6

TABLE 17, cont.
OHIO RIVER

Station	Mile	Date 1939	Volume total	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
Dam 38	503	5-4	2.0	12	56	72	0	55	4	12	1,533	1.88	8.68	45	7.5	14
		5-12	39.8	3	0	108	0	3,768	0	33	1,665	2.59	9.50	15	7.9	17
		5-18	16.6	4	52	40	0	3,456	16	20	1,100	2.71	9.17	8	7.9	20
		5-22	24.1	116	88	44	0	2,372	4	32	430	2.55	8.67	25	7.8	21.5
		6-1	12.4	244	0	168	0	1,198	8	44	230	2.65	7.77	10	7.7	25
		6-5	6.0	232	44	112	0	4,432	12	28	443	2.90	7.25	105	7.8	24
		6-13	1.4	48	0	268	8	380	4	24	1,100	1.98	6.65	95	8.0	23
		6-19	5.1	16	8	20	0	56	0	4	390	2.57	6.08	90	9.0	25
		7-17	2.3	16	30	325	0	212	68	28	930	2.46	7.0	84	7.2	25
		7-31	.87	6	3	87	3	158	9	12	930	3.20	5.80	265	7.5	26
		8-8	.60	40	4	116	8	162	0	0	430	1.72	6.63	70	7.2	26
		8-14	2.3	12	4	136	8	200	36	20	430	2.71	6.08	47	7.7	27
		8-22	1.2	0	8	56	12	680	16	56	230	1.83	6.33	46	7.5	26
		8-28	1.8	20	8	112	12	1,828	56	28	150	2.20	8.20	18	7.6	24.5
		9-5	1.7	24	0	104	12	2,556	4	4	36	2.58	6.46	15	7.8	24
		9-19	1.2	0	0	172	24	196	8	0	9.3	1.81	4.70	10	7.5	23
		9-25	1.8	24	8	1,352	8	80	0	32	240	2.28	6.93	15	7.6	22
		10-9	.53	16	12	185	16	340	4	32	240	2.[illegible]	5.53	8	7.5	21
		10-27	.39	84	0	44	32	348	8	4	1,500	3.02	7.10	7	7.5	17
		10-31	1.1	440	8	252	0	266	0	8	430	1.93	8.79	43	7.5	12
		11-14	.48	276	8	56	0	172	16	20	2,400	2.48	11.13	12	7.3	8
		11-30	2.1	384	12	296	168	136	4	52	2,010	3.37	10.37	0	-	7
Dam 39	531	5-4	1.7	8	104	120	0	160	4	20	240	1.86	8.67	50	7.4	14
		5-12	45.1	56	160	132	0	2,988	16	88	430	2.64	9.53	15	7.9	17.5
		5-16	49.7	20	164	168	0	6,340	8	96	32	2.65	10.35	8	8.1	18
		5-26	26.0	196	0	192	0	3,744	4	60	230	2.44	8.17	5	7.7	24
		6-9	5.7	216	0	212	0	4,596	5	24	144	2.34	7.42	144	8.2	27
		6-15	.48	28	0	32	0	236	4	8	60	2.03	6.05	62	7.8	23
		6-23	.46	72	20	40	0	116	20	8	503	2.86	5.71	215	7.7	26
		7-21	.61	0	8	88	0	136	20	4	137	1.98	6.32	112	7.3	26
		7-27	.73	8	8	84	0	476	8	16	43	1.90	6.82	112	7.3	26
		8-4	.90	28	40	92	56	92	16	4	703	1.15	5.34	89	7.5	26.5
		8-10	1.4	64	12	128	36	584	24	4	36	1.10	6.63	22	7.3	26.5
		8-18	.34	12	24	80	64	44	12	4	23	1.54	5.58	140	7.3	27.5
		8-24	1.1	24	4	70	12	1,324	12		43	1.59	7.20	37	7.8	26.5
		9-1	2.7	4	4	120	4	2,836	0	0	2	4.21	11.53	15	7.7	25.5
		9-7	.52	12	4	120	0	288	0	44	3	2.07	7.87	15	7.9	25.5
		9-15	.71	20	8	128	44	1,732	4	4	1	1.57	6.70	8	7.6	26
		9-21	1.2	12	12	236	12	284	4	0	1	1.57	6.50	15	7.5	24.5
		9-29	3.2	20	60	1,708	16	2,668	0	0	3.6	2.53	10.20	14	8.1	23
		10-13	1.6	76	28	280	112	2,152	0	12	7	2.10	8.55	4	7.5	19
		10-19	.75	0	0	288	20	0	0	12	16	1.76	8.99	5	7.6	16.5
		10-27	1.8	124	24	352	20	92	8	4	24	1.61	8.17	5	7.6	17.5
		11-2	6.0	36	16	56	0	108	0	28	34	2.42	8.71	1960	7.3	13
		11-16	.94	1,412	48	168	4	448	12	8	10	2.20	11.40	144	7.3	9
		11-30	2.0	320	16	116	0	20	4	48	338	1.85	10.93	-	-	7.5

TABLE 17, cont.
OHIO RIVER

Station	Mile	Date 1940	Volume total	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
	547.8	10-15	1.4	15	25	110	0	1,250	5	5	24	3.29	11.58	30	8.4	16.5
	559.5	7-29	.63	5	5	115	10	533	5	0	89	3.26	8.57	13	7.6	30.0
	561	10-16	1.40	30	50	80	0	1,175	0	35	23	3.31	10.90	25	8.4	17.5
	562.6	7-29	.57	0	0	105	0	1,530	0	0	419	1.64	7.64	15	7.6	30.0
	562.6	10-16	.66	0	10	100	10	759	5	30	9.3	2.71	11.40	11	8.5	18.0
	576.1	7-29	.80	15	15	105	5	2,165	5	0	142	2.12	7.40	15	7.4	29.5
	576.1	10-16	1.70	24	12	281		2,215	0	36	4.3	3.02	10.35	11	8.1	17.5
	600	8-9	1.1	6	0	148	0	1,074	0	0	.91	2.20	8.46	8	8.1	28.5
	608.5	8-12	1.4	0	6	58	0	907	0	6	230	2.39	8.25	12	8.0	28.0
	608.5	10-25	.16	0	6	110	0	285	0	0	460	2.52	7.52	5	7.7	16.0
	610	8-12	1.2	0	0	105	0	1,035	5	0	930	2.26	6.54	11	8.0	29.0
	610	10-25	.55	0	0	45	0	330	0	0	1,100	2.43	7.40	8	7.5	17.0
	614	8-12	3.1	12	0	142	25	3,664	0	0	91	2.74	8.35	8	8.1	28.5
	614	10-25	.32	0	5	65	6	285	0	5	1,100	2.40	7.21	10	7.5	17.5
	628	10-23	.21	0	0	120	0	185	0	0	1,100	2.20	7.51	8	7.5	16.0
Dam No. 43	633	10-23	.21	5	0	30	0	110	0	0	43	2.10	7.80	5	7.6	16.5
	637.1	10-23	.57	0	25	60	0	610	0	5	60	-	-	-	7.6	16.5
	662.9	8-19	3.9	5	0	135	5	3,610	5	0	110	3.48	6.86	60	7.7	28.0
	665	8-19	3.2	5	0	170	0	4,240	0	0	150	3.47	6.50	62	7.8	28.0
Dam No. 45	703	8-19	1.6	5	0	65	0	3,115	0	5	75	2.51	5.93	50	7.7	26.0
	711.3	8-21	.27	5	0	15	0	145	0	0	110	2.16	6.35	41	7.5	27.0
	722.7	8-21	3.60	5	0	65	0	2,895	5	10	46	2.09	6.30	38	7.5	27.0
	730.6	8-21	5.10	5	5	155	30	6,300	0	5	46	2.40	6.29	50	7.5	26.5
Dam No. 46	756.5	9-4	.09	0	0	135	0	350	0	0	24	1.78	6.74	60	7.5	24.0
	756.5	10-30	1.1	5	0	525	10	70	0	0	3.6	2.55	9.33	10	8.1	17.5
	760	9-4	.86	20	0	165	5	5	0	5	110	3.60	7.18	60	7.5	23.5
	760	10-30	1.8	0	0	1,225	0	170	0	30	43	2.35	9.40	8	8.0	16.5
Dam No. 48	777.7	9-4	1.2	0	0	80	0	550	0	5	24	1.38	7.33	60	7.5	24.0
	777.7	10-30	.56	0	0	1,565	0	75	0	5	23	1.77	8.57	10	7.9	16.5

TABLE 17, cont.
OHIO RIVER

Station	Mile	Date 1940	Volume	Chr.	Cry.	Chl.	Myx.	Bac.	Eug.	Pro.	B. coli	BOD.	D.O.	Tby.	pH	Temp.
	791	9-4	.52	0	0	165	0	1,285	0	15	46	2.20	7.31	50	7.6	23.5
	791	11-1	.49	0	0	35	0	220	0	0	43	1.99	9.17	12	7.9	17.5
	797.7	10-29	1.1	0	0	225	0	220	0	5	240	2.76	9.04	13	8.3	18.0
	803	9-3	2.8	0	0	1,650	0	1,165	10	0	75	1.45	7.21	63	7.6	25.5
	803	10-29	.69	0	0	50	10	215	0	5	43	2.43	9.73	13	8.4	16.5
	809	9-3	2.7	30	0	3,050	0	1,270	10	15	150	1.60	7.14	65	7.6	25.5
	809	10-29	.98	0	0	925	5	340	0	0	23	2.78	9.97	13	8.5	18.0
	829.1	9-11	2.0	15	0	255	5	285	5	10	24	1.99	8.54	22	7.7	22.3
	829.1	11-6	6.8	15	0	390	20	2,200	0	60	43	2.18	9.68	13	7.7	14.5
Dam No. 49	845	9-11	1.3	5	0	240	0	525	15	15	24	1.80	8.36	18	7.7	23.5
	845	11-6	8.0	0	10	210	0	2,295	10	35	46	2.00	9.62	13	7.7	15.0
	852.3	9-11	.98	20	0	1,010	40	540	0	15	15	1.91	9.38	18	7.9	24.0
	852.3	11-6	4.3	0	35	165	0	1,300	0	35	24	2.63	9.87	15	7.5	14.0
	864.8	9-10	1.6	15	0	305	115	600	15	25	9.3	2.98	8.49	18	7.9	24.5
	864.8	11-5	2.5	15	10	490	5	265	0	35	24	1.97	9.50	15	7.8	15.5
	870.7	9-10	.30	10	5	639	136	352	0	5	9.3	1.43	8.46	15	7.9	25.0
	870.7	11-5	1.7	15	0	760	5	4,025	0	15	7.5	1.90	9.40	18	7.8	16.0
Dam No. 50	876.8	9-10	.26	0	0	300	35	365	10	0	2.3	1.49	8.63	18	8.0	24.5
	876.8	11-5	2.0	10	5	1,290	0	1,400	0	30	9.3	1.74	9.52	15	7.8	17.0
	891.6	9-20	.91	0	0	1,870	60	150	0	0	.73	2.00	9.44	13	8.4	22.5
	927.3	9-20	.96	0	0	1,110	125	105	0	10	2.3	1.65	9.59	12	8.3	24.0
	934.3	9-23	.04	0	0	80	30	5	0	0	2	1.84	8.99	15	7.9	25.0
	934.3	11-22	1.40	15	15	85	0	965	0	10	2.3	8.34	10.40	18	7.7	12.0
Dam No. 52	938.9	9-23	.09	5	0	75	60	25	0	0	7.5	1.00	8.70	12	7.9	25.0
	938.9	11-22	3.8	30	20	105	0	1,370	0	5	.91	1.86	11.57	18	7.8	11.0
	962.6	9-23	.24	0	0	205	30	25	0	0	-	-	-	-	-	26.0
	962.6	11-22	2.0	15	10	100	0	2,424	0	0	9.3	2.31	12.76	20	7.9	10.5
	978	10-3	.62	5	0	225	50	540	0	10	2.3	1.50	9.39	10	8.0	20
	978	11-25	4.2	10	25	170	0	1,845	0	0	2.1	2.45	11.80	125	7.6	9.5
	981	10-3	.34	5	0	60	20	385	0	0	24.0	1.59	9.31	130	7.9	19.5

APPENDIX I

SCIOTO RIVER BIOLOGICAL STUDIES

SCIOTO RIVER BIOLOGICAL STUDIES

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SCIOTO RIVER BIOLOGICAL STUDIES

Introduction

The lower half of the Scioto River was the object of an intensive study during thirty months from February, 1938, to July, 1939. During that time, the plankton was studied both in the field and in the U. S. Public Health Service laboratory at Cincinnati at weekly intervals, and the life of the bottom sediments at less frequent intervals. Reference may be had to Volume III of the Final Report of the Ohio River Pollution Survey(1) for the hydrography of the stream, population figures, and extent and sources of pollution, also to the Drainage Basin Committee's reports,(2) while Public Health Bulletin 276(3) gives the detailed hydrobiological findings of the Scioto River studies.

Headwater Streams

The headwaters of the Scioto and Olentangy Rivers, above Columbus, and the headwaters of the five creek basins - Paint, Deer, Darby, Big Walnut and Little Walnut - are located in areas where population is dense, where industry is concentrated, and where agricultural productivity is high. Almost all of the headwater streams, therefore, receive heavy loads of human, some industrial pollution, and extensive agricultural drainage, and they are consequently well fertilized. Furthermore, the gradients of these streams are slight and, in their lazy flow, time is allowed for aging of the water. Because of these two factors, biological productivity should be high.

No reliable index of biological productivity for long periods of time is available for the headwaters, but for some stations series of samples covering a few weeks have been examined. For many other points two samples, one above and one below a town or source of possible pollution, have been examined. The general idea gained from these scattered observations is that biological productivity, as far as plankton is concerned, is high in the headwater streams. For example, one of the samples from the Scioto in the vicinity of Kenton, very close to its source, contained 35 species of plankton organisms, some of them in large numbers (October 2, 1939).

In the small headwater streams, radical differences in the plankton above and below a town are sometimes apparent and may be correlated with chemical and bacterial findings indicative of gross pollution below the town. Paint Creek, above and below Washington Court House, and above and below Greenfield, offers excellent examples. In December, 1939, and on into March, 1940, the creek above both towns showed large numbers of Chrysophyceae and Cryptophyceae, with abundant D.O., low B.O.D. values, and low coliform counts. Below the towns these conditions were reversed; at times there was no oxygen in some parts of the creek below Washington Court House. At other times or in other stretches of the creek, there were D.O. values of 10.6 p.p.m., along with 10.9 p.p.m. B.O.D. and a coliform count per ml. of 1000 (most probable number). Cryptophyceae and Chrysophyceae were generally less in numbers below the towns. The flora and fauna were abundant, but principally made up of forms characteristic of activated sludge or a trickling filter - Sphaerotilus, Beggiatoa, Chromatium and not infrequently large numbers of ciliate protozoa. A few species of Euglena were usually present, even if lacking above the towns, but only one species, Euglena viridis, was ever abundant; at one time it was so abundant below Washington Court House (however, in a recovery zone) as to constitute a bloom in late December and early January. There was sufficient green plankton in some of the samples to have been a factor in accouting for the high D.O. values.

Above Columbus Sewage Plant Outfall

Columbus uses much of the river water at times of low flow, but there was always a fair population of plankton organisms at the lower margin of the city, to provide abundant reseeding of the water returned to the river via the sewers and sewage disposal plant. A sampling point located at the lower margin of the city was the uppermost station for routine sampling in the detailed study of the river. It was just below a low head dam and its plankton population generally consisted of organisms that lived principally by photosynthesis and were not dependent on organic matter. That is, clean water organisms were generally predominant at this station.

The Scioto River, from the lower margin of the city to the sewage treatment plant outfall, was frequently sluggish in flow and, besides receiving storm water drainage from the city, also received some raw sewage. It rapidly deteriorated in sanitary quality, and on at least two occasions appeared to be septic about a mile below the uppermost regular sampling point. In effect, the storm drainage and some raw sewage created a zone through which many organisms could not pass, because of oxygen deficiency, H_2S poisoning, and possibly other causes. Only a few species showed a rise between Columbus and Shadeville, the second sampling station, but it was not at all unusual to find empty shells, or dead individuals, of clean water types, at Shadeville or in the intervening stretch, and the work sheets for the survey sometimes have notations to that effect.

Objectives

The plankton work of the Scioto River Survey had several objectives. One was to show what organisms were to be found in the stream, over a long period of time. It was hoped that this would provide a fairly comprehensive list of river plankton species. Most plankton forms are cosmopolitan, and it was not anticipated that extremes of environment, other than the initial badly polluted stretch, would be encountered, so a normal river plankton was envisaged.

A second objective was to determine what, if any effect, Columbus sewage exerted on the plankton, especially with regard to the successive modes of treatment - trickling filter, primary sedimentation and complete treatment.

A third objective was to seek correlations between physicochemical conditions, coliform counts, and the qualitative and quantitative plankton findings. This last would involve an evaluation of "indicator species," as well as determining the causative factors for peaks in the plankton population.

Results

It is not too much to say that all these aims were achieved, and in addition certain refinements in the tachnique of handling plankton were evolved, while, as a side issue, a number of new species of algae and Protozoa were described.

Species Found - The Scioto yielded 448 groups, genera or species of plankton organisms during the survey. One whole class of algae, the dinoflagellates or Dinophyceae, was very poorly classified as to genera and species. They were few in number in the Scioto, as in streams generally, but are often abundant in lakes and reservoirs. A number of genera, e.g., Chlamydomonas, were not classified to species. Conversely, because of the technique followed, it was possible to identify and count a great many very small organisms, not heretofore usually considered in such surveys. Certainly 448 species or groups of organisms have not heretofore been described from any stream. Subsequent work, including very detailed studies of Tanner's, Laughery, Hogan and Four Mile Creeks; the Cumberland, Duck, Licking, Little Miami and Miami Rivers, all within the Ohio Basin, have confirmed the basic nature of the plankton list. This has also been shown to be substantially correct by less detailed studies of many Ohio Basin streams as well as some studies of Atlantic and Gulf Coastal streams, and the Columbia River of the Pacific Coast. New species are found elsewhere from time to time, but thus far the great majority of forms found elsewhere has corresponded closely with those found in the Scioto. This even holds true for relative numbers - a species common in the Scioto tends to be common elsewhere, even if the abundance in the Scioto and the second source is in a ratio of 10 to 1 or higher.

Columbus Sewage Effects - With regard to the second objective, there was ample evidence as to the effect of the Columbus sewage. There was a large number of species which occurred with some frequency at the lower margin of the city. Some clean water types occurred here in abundance, but more commonly, numbers of all organisms were low at this station, and they decreased still more, until at Shadeville the low population point for most of the enumerated organisms was reached. The few exceptions were sewage-tolerant forms typified by Sphaerotilus. It is to be noted also that some forms appeared at Shadeville which were not found above Shadeville; these too were usually sewage-tolerant forms, as certain ciliate protozoa.

A short distance below Shadeville, an increase in the protistan population of the stream began, and this increase reached very high numbers. This was evidence of the fertilizing power of the sewage plant effluent. The types of organisms were those usually found in recovery or clean water zones; for example, Big Walnut Creek often poured large numbers of Chrysophyceae into the river, and these did not die off, as they did in the stretch between the city margin and Shadeville. Evidently the effluent from the sewage treatment plant provided better water than that below the city but above the treatment plant outfall. At Shadeville there were perhaps more organisms typical of carbonaceous oxidation than at any of the other stations, but they soon disappeared and those typical of nitrogenous oxidation, or those dependent on photosynthesis quickly became the bulk of the population. From a biological standpoint, the plant effluent greatly enriched the river, but with material already far along towards stabilization.

In one respect the findings were disappointing. There was no marked difference in the stream flora and fauna traceable to disposal by trickling filter, primary sedimentation or complete treatment. There were differences in the coliform counts and also chemical differences undoubtedly due to the three types of treatment, but it has long been known that a stream recovers biologically before it recovers otherwise, and such was the case here.

Correlation between Plankton Findings and Other Data - The third objective, correlations between plankton life and other sanitary indices, was not expected to be achieved for all plankton types. But for some species or groups it was well defined. For certain species or groups of species, as shown by the Chrysophyceae in Figure 1, there was an abrupt drop in population at Shadeville, followed by a gradual rise downstream, with a tendency for the population curve to flatten out or decline in the lower part of the river. Since this figure is based on weekly counts of the organisms present at 13 stations over a river length of 118 miles, and covering 30 consecutive months, such distribution may reasonably be assumed to reflect the response of the organisms to conditions obtaining in the river. The drop at Shadeville is unquestionably a response to the pollution there. It may be a response to some particular phase of the pollution, but certainly to the sewage plant effluent. As pollution abates downstream, due to dilution, biochemical action, etc., numbers once more increase. Organisms behaving thus over a period of time may therefore be used as indicators of unpolluted water, when present in large numbers. It must be emphasized, however, that evidence should not be adduced from one sample, because a flowing stream is an ever-changing environment, and because the phenomenon of "blooms" of aquatic microorganisms - those sudden appearances of enormous but transient populations - are so little understood.

Only two whole groups of organisms, the Chrysophyceae or yellow flagellates and the Cryptophyceae or olive-green flagellates, behaved as shown in Figure 1, in the Scioto. In other groups, individual species or genera showed diverse reactions. Figure 2 shows the behavior of one genus and two species of diatoms (Bacillarieae). Asterionella formosa reacts adversely to sewage pollution; Nitzschia acicularis, while at least indifferent to the degree of pollution at Shadeville, still

Fig. 1

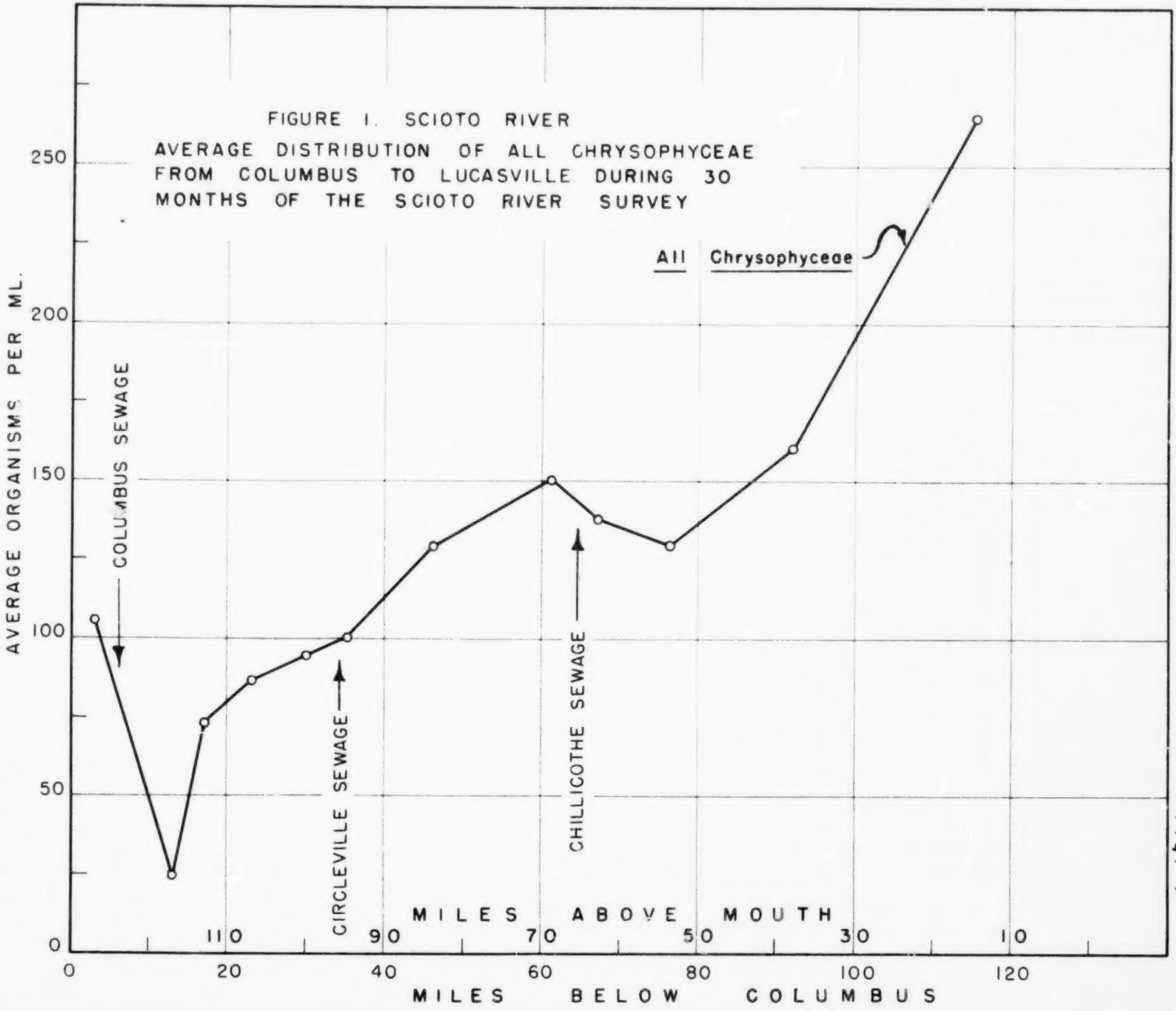

FIGURE I. SCIOTO RIVER
AVERAGE DISTRIBUTION OF ALL CHRYSOPHYCEAE
FROM COLUMBUS TO LUCASVILLE DURING 30
MONTHS OF THE SCIOTO RIVER SURVEY

thrives best in clean water. *Navicula spp*, however, shows a great increase in the polluted zone, which is apparently reflected by the less degrees of pollution at Circleville and Chillicothe.

It is a virtual impossibility to distinguish the species of this genus in survey work. But it has been well established, by Kolkwitz(4) and others, that some species of *Navicula* apparently prefer polluted water while others attain their maximum development elsewhere. Such a polymodel curve as in Figure 2 might well result from counting two or more indistinguishable species.

Figure 3 shows the distribution in the Scioto of a typical organism which favors sewage-polluted water as a habitat - *Sphaerotilus natans*, the sewage fungus. Figure 4 shows the behavior of certain species of *Euglena* in the Scioto. As a rule, members of this genus tend to be abundant only when the temperature is high, hence these average figures for all months of the year are low. Figure 4 includes those members of the genus which tend to be most abundant in polluted water. *Euglena oxyuris* apparently favors organic pollution also, but its members were rarely large. Conversely, some members of the genus, *E.mutabilis*, *E.spirogyra*, are rarely, if ever, found in polluted water, while great blooms of *E.polymorpha* and *E.sanguinea* have been noted in unpolluted situations. The highest averages for the species shown in Figure 4, however, are not in the badly polluted zone but in river stretches where there has been an increase in D.O., with a drop in B.O.D. and coliform counts. In other words, the highest numbers tend to appear in the zone of nitrogenous oxidation and not in the zone of carbonaceous oxidation.

It is perhaps unfortunate that, in this biological study, conclusions are drawn from the distribution of suspended forms almost to the exclusion of bottom forms, but physical limitations compelled this. There is little doubt, for example, that the peak of the diatom *Navicula* at Shadeville is influenced by the numbers swept off the bottom of the very large riffle just above this point. Riffles tend to be liberally carpeted with diatoms at times, and since some of them are swept into suspension by the current, a peak such as the one at Shadeville could be misinterpreted. It could be due entirely to the fact that the physical nature of the substrate at that point favored the growth of diatoms and the current swept them into suspension, where they were readily available for counting, whereas both the mud bottom and decreased current at a lower station militated against a high count. In such a case, pollution might not even be a factor in the distribution of this genus of diatoms.

Fig. 2

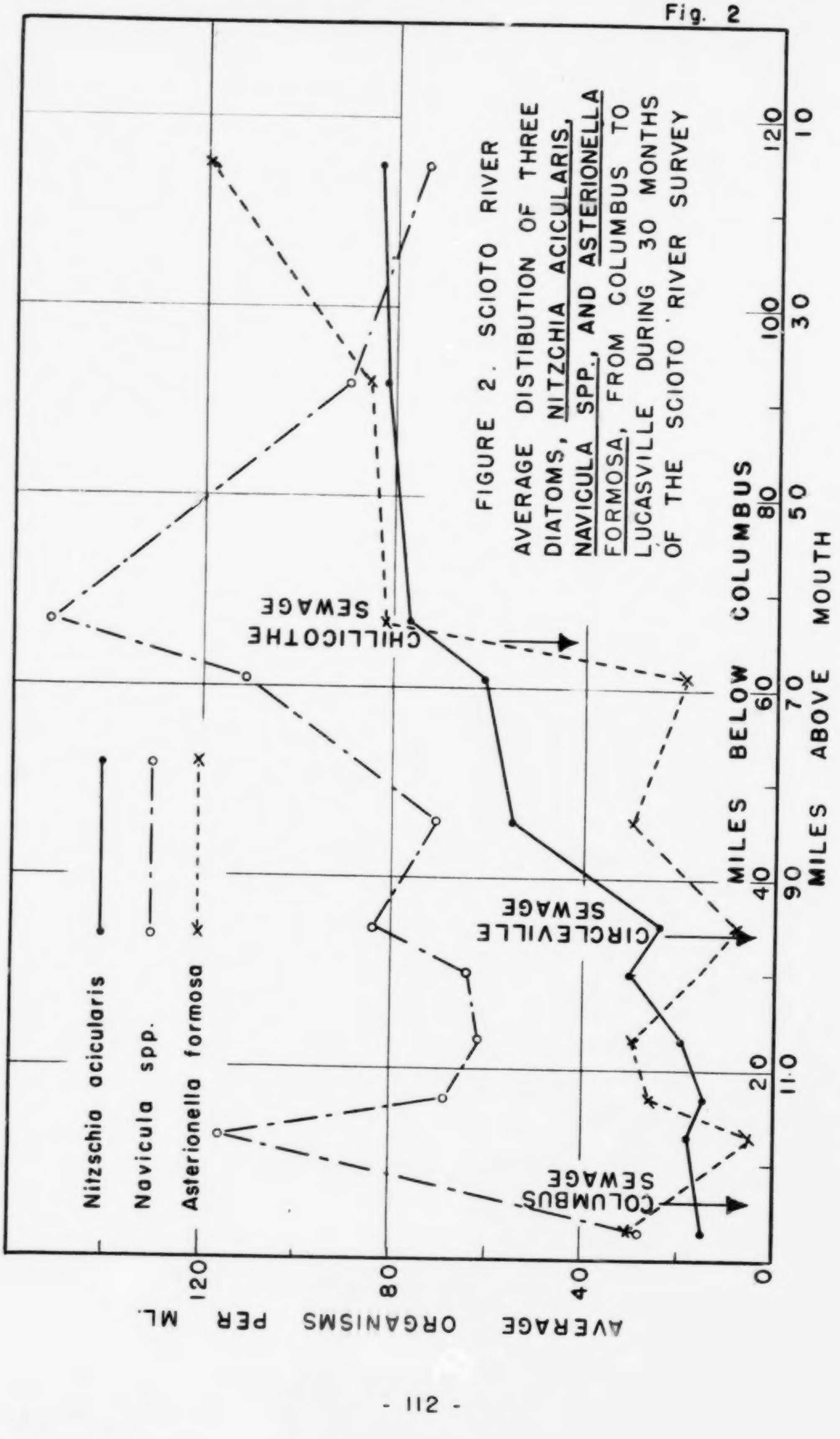

FIGURE 2. SCIOTO RIVER

AVERAGE DISTIBUTION OF THREE DIATOMS, *NITZCHIA ACICULARIS*, *NAVICULA SPP.*, AND *ASTERIONELLA FORMOSA*, FROM COLUMBUS TO LUCASVILLE DURING 30 MONTHS OF THE SCIOTO RIVER SURVEY

Fig. 3

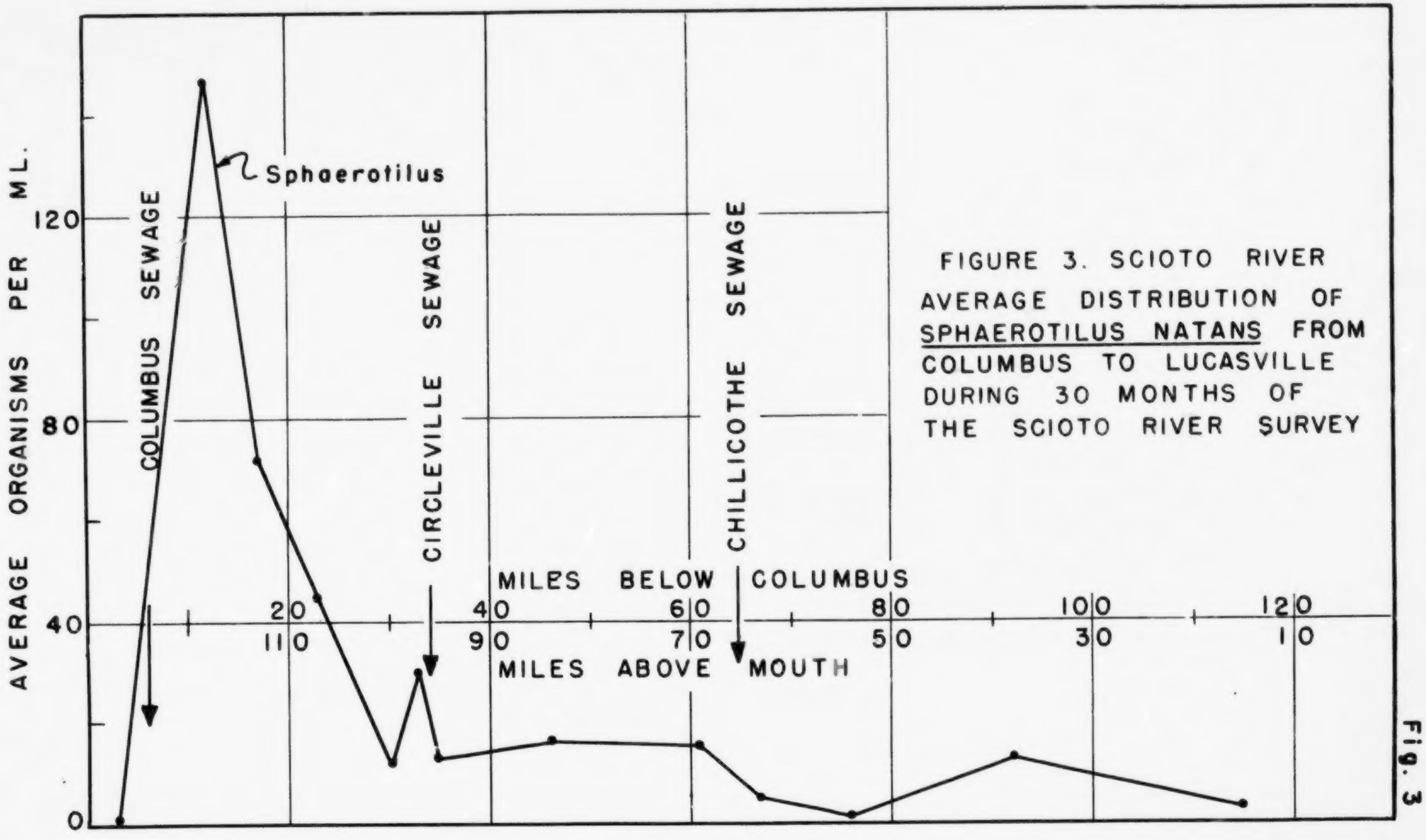

FIGURE 3. SCIOTO RIVER
AVERAGE DISTRIBUTION OF
SPHAEROTILUS NATANS FROM
COLUMBUS TO LUCASVILLE
DURING 30 MONTHS OF
THE SCIOTO RIVER SURVEY

Fig. 4

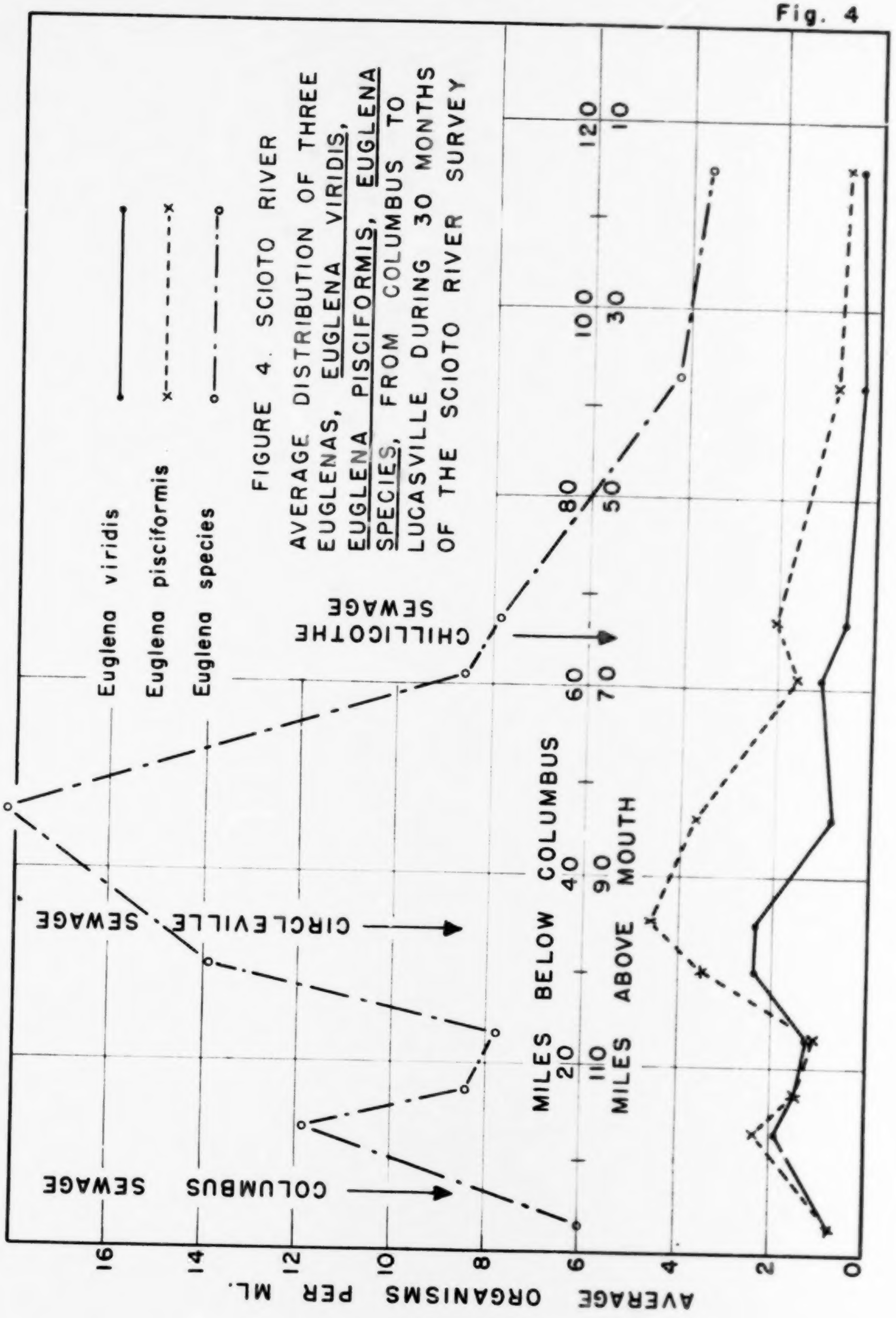

FIGURE 4. SCIOTO RIVER
AVERAGE DISTRIBUTION OF THREE EUGLENAS, *EUGLENA VIRIDIS*, *EUGLENA PISCIFORMIS*, *EUGLENA SPECIES*, FROM COLUMBUS TO LUCASVILLE DURING 30 MONTHS OF THE SCIOTO RIVER SURVEY

Conclusions

While the many factors influencing biological life demand extreme caution in the interpretation of results, certain facts seem fairly well established.

(1) Some organisms tend to be abundant, in their season, in river stretches where the water is of good sanitary quality. These include members of the Chrysophyceae, the Cryptophyceae, a few Cryptophyceae, some diatoms, and a few of the ciliate protozoa.

(2) Other organisms, notably fungi, certain bacteria, some species of Euglenophyceae, some species of Volvocales, and ciliates generally, if present in abundance, in their season, are reasonably indicative of recent organic pollution.

(3) Many organisms, abundant in sewage-disposal plants or foul pools, are not common to the Scioto at any point, but their absence may be due to insufficient organic pollution, or to the fact that they are primarily bottom-dwelling, creeping or crawling forms.

(4) The vast majority of plankton organisms in the Scioto are not found in either the most polluted section or the cleanest section of the river. This is probably not due to any specific ecologic factors in these regions, but rather to the fact that these organisms are tolerant of a wide range of environment. It should be apparent that either gross pollution or extreme purity of water represent much more circumscribed environments than the region in between these two. This region of course includes the region of nitrogenous oxidation, but laboratory experiments for the most part fail to show any marked dependence of organisms of this region upon the existence of other than extremely small quantities of available oxidizable nitrogen.

(5) A well defined seasonal succession is apparent for many of the Scioto River species. Some are most abundant in winter, others in the spring, but the great majority are most abundant in the late summer. This is far more apparent for phytoplankton than for zooplankton, as shown by Figures 5 and 6. This seasonal succession is probably influenced by dilution, clarity of water, increased illumination and other factors, as well as temperature, but too much stress cannot be laid on any single factor. For example, the same seasonal succession occurs

in pools or lakes, where clarity due to silt and dilution vary but little during the yearly cycle.

(6) Plankton production in the Scioto is extremely high, as compared with other rivers which have been investigated. Inevitably this is due in part to fertilization by the organic (and other) wastes of its densely populated basin, but there are other factors which cannot be discounted, as age of water. Nor can the fact be discounted that enormous, if transient, populations occur in pools which receive almost no drainage, or known organic pollution.

(7) More species have been found in the Scioto than reported from any other river in available literature. The species list is believed to be fairly comprehensive, as well as representative for rivers of a comparable class. In part at least, the increased species list is believed due to improvement in the technique of examination.

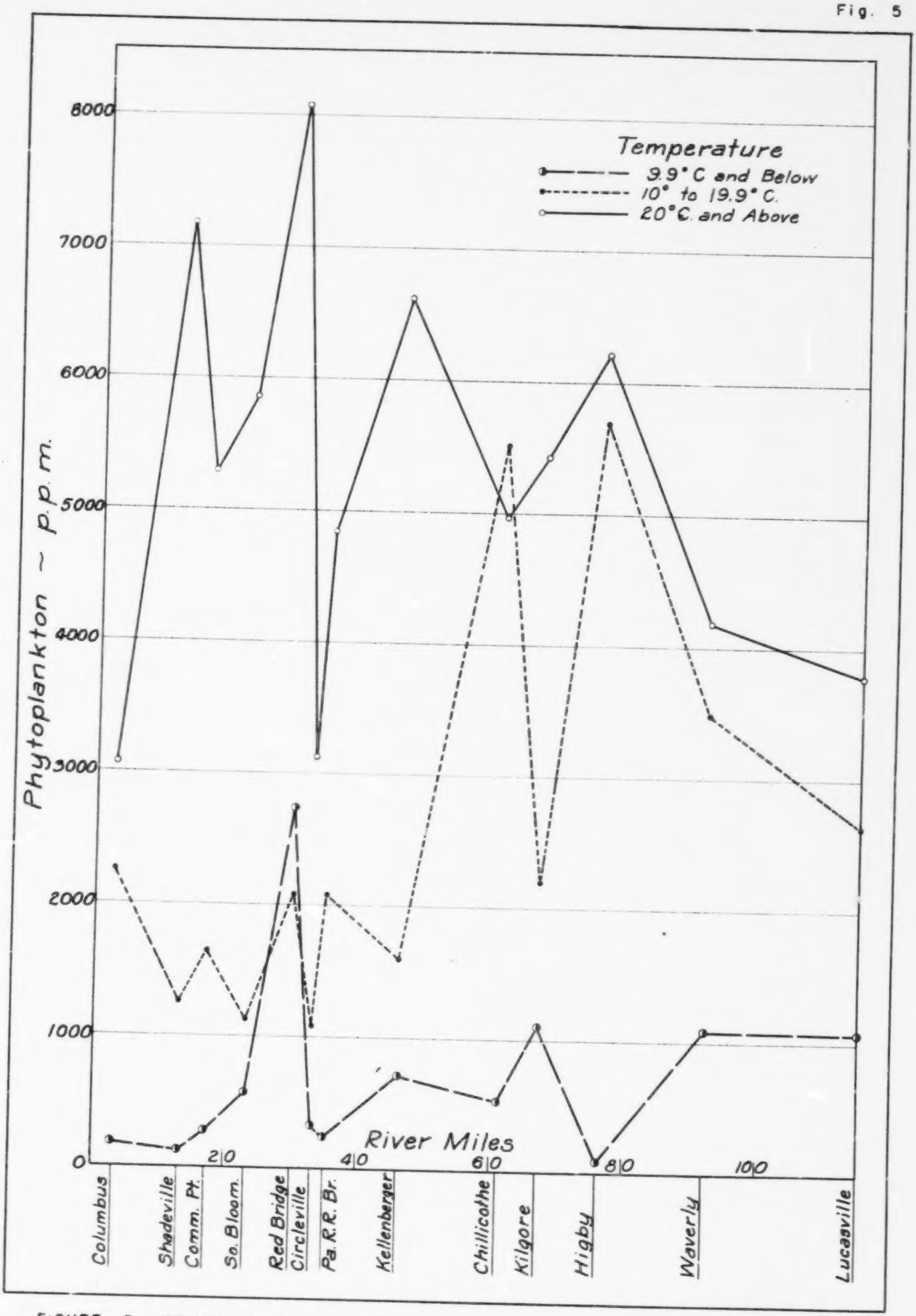

FIGURE 5. SCIOTO RIVER - PHYTOPLANKTON IN PARTS PER MILLION BY VOLUME AT EACH STATION DURING LOW FLOWS FOR THE THREE TEMPERATURE RANGES.

Fig. 6.

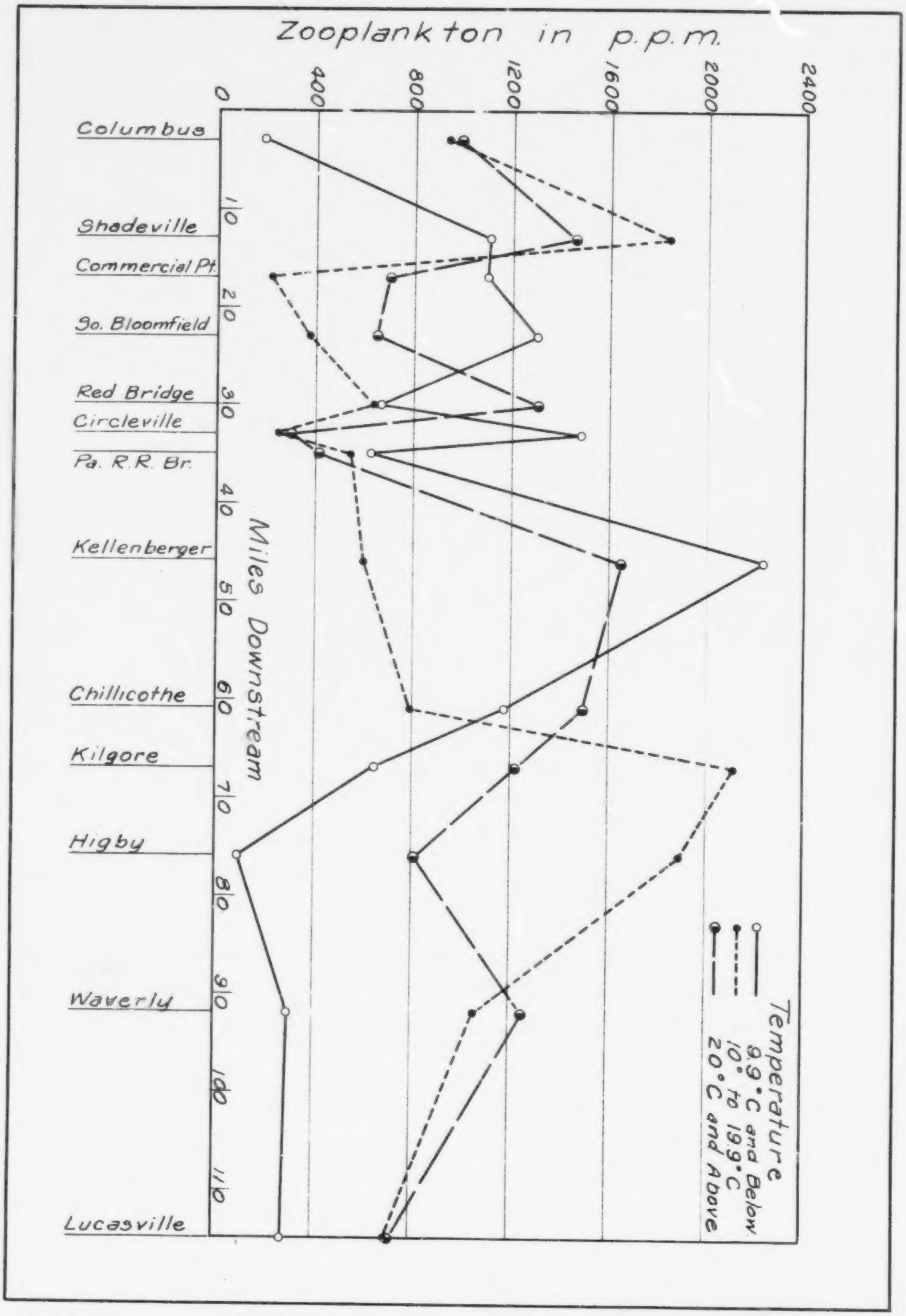

FIGURE 6. SCIOTO RIVER - ZOOPLANKTON IN PARTS PER MILLION BY VOLUME AT EACH STATION DURING LOW FLOWS FOR THE THREE TEMPERATURE RANGES.

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APPENDIX II

DISCUSSION OF THE BIOLOGY AND POLLUTION OF THE TENNESSEE RIVER

DISCUSSION OF THE BIOLOGY AND POLLUTION OF THE TENNESSEE RIVER

The Tennessee River receives runoff from an area of 40,600 square miles, draining portions of the following seven southern states: Virginia, North Carolina, Tennessee, Georgia, Alabama, Mississippi and Kentucky. The character of the valley varies from the steep forested slopes of the Pre-Cambrian formations in the east, through the gently rolling calcareous deposits of the Cambrian in the main valley to the Pennsylvanian of the Cumberland Plateau. The runoffs from each of these areas have a decided effect upon the general appearance, biology, and mineral constituents of the Tennessee River and its tributaries.

The river itself is rapidly becoming a chain of impounded lakes or reservoirs from its mouth to Knoxville, 650 miles upstream. Seven of the nine run-of-the-river dams are in service and the two remaining dams, the Kentucky Dam near the mouth and Fort Loudoun Dam just below Knoxville, are under construction. There are now thirteen TVA-operated dams on the tributaries which provide storage as well as additional power. Five more such dams are under construction. In addition to these, there are six major privately owned and operated hydroelectric plants and a number of smaller developments (see attached map of the Tennessee River System). Such developments forming reservoirs in a normally free-running stream are accompanied by a series of biological readjustments to the change from lotic to lenitic conditions.

Another factor having a direct bearing upon the biology of the Tennessee River System is the pollution received from the municipalities, industries, and the organic matter and silt washed from the land itself. In general, the area is predominantly rural, having but few large cities. The three largest cities, Chattanooga, Knoxville and Asheville, account for approximately one-half of the sewered population of about 590,000. It is estimated that about twenty per cent of the domestic sewage receives treatment and that much of this treatment is ineffective due to obsolete and overloaded plants. There are now

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a few highly developed industrial areas, chiefly in the eastern section of the Valley. The industrial activities, however, are becoming more numerous and widespread due to the large amount of available power, raw materials, and to the need of additional capacity of plants producing essential war materials. There are perhaps three main types of wastes now present as classified by their effect upon the aquatic life.

The first type of waste consists of those exerting an oxygen demand on the stream. In the normally clean streams in the Valley the ratio of the amount of dissolved oxygen to the five-day B.O.D. may at times exceed seven. This ratio decreases as pollution is added, passing Streeter's limit of one, which is considered necessary for the maintenance of favorable conditions, to reach a very low value in the more polluted sections. The sections in the main river below Knoxville and Chattanooga are polluted by domestic sewage and industrial wastes. The D.O.-B.O.D. ratio for the section below Knoxville has fallen below one for short periods of low flow, but below Chattanooga it has remained well above this value.

The French Broad River below Brevard is highly colored and polluted by paper mill wastes. Here the D.O.-B.O.D. ratio was found to be slightly more than one, but the color persists for a considerable distance downstream. At Asheville, the stream receives domestic sewage and the industrial wastes from a large viscose rayon plant. The rapid turbulent flow below this point results in a high D.O.-B.O.D. ratio. The river receives another large load of pollution from the Pigeon River, originating at a pulp and paper mill at Canton, North Carolina. This stream is black all the way to its mouth, and contains less than one p.p.m. of D.O., even below Waterville Lake. The effect on the French Broad is to lower the D.O.-B.O.D. ratio to about 1.5 just below the mouth of the Pigeon River and to color the entire river from that point to its mouth.

Beaver Creek receives a heavy load of untreated domestic sewage and the industrial waste from a paper mill at Bristol. This stream is dark-colored even at its mouth and is septic in stretches, but near its mouth has a D.O.-B.O.D. ratio well above one; however, it does influence the South Holston into which it discharges by reducing the ratio from around seven to less than two at critical periods. At Kingsport the South Holston again receives domestic sewage, and industrial wastes from a large chemical and acetate-cellulose plant and a paper mill. Below these wastes the ratio is consistently below one during the summer season, and the stream does not entirely recover before it enters Cherokee Reservoir 35 miles below.

Emory River at Harriman, Tennessee, receives the untreated domestic sewage from that town, wastes from a hosiery mill and from a paper plant. The ratio of D.O.-B.O.D. is reduced by these wastes from about 10 to less than one and the black color extends down this arm of the lake to the main body of Watts Bar.

Scott Creek receives a heavy load of industrial wastes from a tannery and paper mill at Sylva, North Carolina. It is highly colored and almost devoid of oxygen and seriously affects the Tuckasegee River. The D.O.-B.O.D. ratio of this stream twenty miles below Scott Creek is less than one, and the wastes color the Little Tennessee River, into which the Tuckasegee River discharges, from that point to its mouth.

This briefly describes the most important sections polluted by Type 1 wastes. The second type consists of those wastes which materially lower the pH of the waters. In this classification belongs the drainage from the abandoned coal mines of the Cumberland plateau. The waters of the Clinch and Powell River systems, draining such wastes, are highly acid until they leave the Pennsylvanian region and enter the Cambrian where the acid is neutralized by the lime formations. Another stream which is highly acid, due however to the wastes discharged from a copper refining plant, is the Ocoee River. The pH of this stream has been as low as 4.5 at times.

The third group is chiefly composed of silt and minerals in suspension. Most of the streams draining the more developed areas carry considerable amounts of silt. However, there is one stream, the Duck River, which receives large amounts of silt from the phosphate washing plants near Columbia, Tennessee. It has been reported that this material has at times killed large numbers of fish.

The Tennessee River has a high biological productivity, as is evidenced by the qualitative and quantitative abundance of its fishes. With the impoundment of the main stream reservoirs, the production of fish has beengreatly increased. Standing populations of over 800 pounds per acre have been recorded on the lower reservoirs. A valley-wide survey of fishes has to date taken 83 genera containing 174 species comprising 186 forms. These include 12 species of game fishes, 11 species of pan fishes, 10 species of food fishes, and 18 common species of coarse fishes, as well as many other species of coarse and forage fishes. These fishes are important to the Valley from a recreational, economic, and public health or nutritional standpoint. A census conducted in 1940 showed that commercial fishing with set lines yielded well over a million pounds in the four lower reservoirs alone. This fishery supported wholly or in part over 1300 people on the three lower reservoirs. Fishermen counts made in 1940-41 indicate that the four lower reservoirs annually supported 1,200,000 man-days of fishing, a large part of which was fishing for food. Thus the fisheries of the Valley constitute a valuable source of meat and play an important role in the nutrition and health of the people of the Valley.

In comparison with other rivers of comparable size, the lower portion of the Tennessee River is relatively free of pollution, the most serious effects of pollution being largely confined to the main tributaries in the upper end of the Valley. The biological effects of pollution of the Tennessee River may in general be attributed to the three types of pollutants previously described: (1) Those which bring about oxygen depletion and eliminate all organisms except those which can survive under anaerobic conditions; (2) Those which produce excessive acidity or otherwise directly toxic conditions and thereby eliminate all fish and other dominant organisms; (3) Those which bring about an excessive amount of silting and decrease or eliminate aquatic life through the mechanical effects of smothering and the destruction of the natural habitat.

An outstanding case of the effects of gross pollution on the Tennessee watershed is that of the Pigeon River. The effluent from a large paper mill enters the headwaters of this stream. All fish life has been eliminated for a distance of approximately 25 miles, and the bottom fauna confined to those forms which can live under anaerobic conditions. In the remaining distance of about 40 miles to the junction with the French Broad River, the bottom fauna and the fish life is confined to a few species which are tolerant to pollution. Carp,common suckers, and a few minnows are the only species left of a once rich fish fauna. This condition prevails even though the stream drops 1300 feet in the last 40 miles and receives abundant aeration.

Hyperacidity due to coal mine wastes has totally destroyed the fish life and insect fauna in some of the streams tributary to the Emory and Clinch Rivers.

Silting in the Ocoee River due to mine waste and erosion has filled pools, covered riffles, and destroyed many fish-producing areas.

The reservoirs of the Tennessee System may in general be divided into two types, tributary reservoirs and run-of-the-river reservoirs.

The tributary reservoirs are located on tributary streams in the upper part of the Valley. They have a decided chemical and thermal stratification and little river influence, because of the relatively large storage volume in comparison to the inflow. Also, these reservoirs are usually characterized by the formation of density currents which at times cause a rather complex stratification (Wiebe, 1940). They usually have one major fluctuation each year, the water level being high during the spring and summer and low during the fall and winter, water levels frequently varying as much as 100 feet during the year.

Because of the clearness of the water and the typical lenitic conditions produced by storage of practically all inflow during the spring and summer months, the tributary reservoirs have a higher population of plankton than the run-of-the-river reservoirs. Due to the wide annual fluctuation, the aquatic vegetation which normally occupies the littoral zone of lakes is absent from these reservoirs, and the bottom fauna is greatly reduced. Such bottom fauna as is present is largely confined to the hypolimnion and is mainly restricted to such forms as oligochaet worms, chironomids, and Chaoborus, which can exist under the anaerobic conditions which frequently occur there.

The fish population of the tributary reservoirs differs from that of the run-of-the-river reservoirs in having a higher relative abundance of game species but a lower total population in pounds per acre. Because of the clear waters, smallmouth bass, black crappie and wall-eyed pike predominate.

The run-of-the-river reservoirs are located along the main channel of the Tennessee River. In general these reservoirs may be divided into three sections: an upper third where the water is confined primarily to the original channel; a middle third where the water overflows the original banks (natural levees) of the stream; and a lower third where the lake extends to the fairly steep margin of the river flood plain. Because of their relatively small volume in relation to inflow and outflow, river conditions predominate and there is seldom any chemical or thermal stratification. In addition, the water of these reservoirs is generally more turbid than that of the tributary reservoirs, becoming quite muddy during flood conditions.

Under normal conditions, in the upper sections of these reservoirs there is always a perceptible current and the water is more turbid than in the lower sections; likewise, each reservoir is generally less turbid than the one next above it and silting is correspondingly reduced. The over-all fluctuation of water level is much less than on the tributary reservoirs, usually ranging from 2 to 10 feet in different reservoirs. In summer there are frequent minor fluctuations in water level coupled with a gradual seasonal drawdown extending into the winter period. Turbidity, fluctuation, and other factors such as the activity of certain coarse fishes, greatly inhibit the growth of aquatic vegetation.

The plankton population of the run-of-the-river reservoirs is highest in the clear water of the low sections, and is lowest in the upper sections where current and turbidity are more pronounced. In general, in passing from one reservoir to the next lower, an increased production of plankton is correlated with the decreased turbidity. The greatest production of plankton occurs during the early winter when the flow is largely composed of clear water from the tributary reservoirs.

Bottom fauna is much more varied and abundant in the run-of-the-river than in the tributary reservoirs. The predominant forms in order of their relative abundance as determined by volume are Ephemeroptera, Chironomidae, Chaoborinae and Oligochaeta. The mayflies, which consist chiefly of one species, Hexagenia bilineata, reach their greatest abundance just below the lower limit of the zone of fluctuation, and in silty bottoms may extend to depths of 30 or more feet. The phantom midge, Chaoborus, and the oligochaet worms are largely confined to the deeper waters in the silted lower sections of the reservoirs. Chironomids are numerically more abundant than any other form and occur from the shallow to the deep waters. Certain of the smaller species are apparently well adapted for existence in the zone of fluctuation, where they reach their greatest abundance; other larger species attain their greatest abundance in the deeper waters of the lower sections of the reservoirs. In general, the forms which occupy the zone of fluctuation are those having a short life cycle or well developed powers of locomotion. Among these the most important appears to be the corixid, Trichocoriza burmeisteri, which attains tremendous abundance in the shallow waters and constitutes an important item in the food of certain species of fish.

The standing population of fishes is much greater in the lower reservoirs than in the tributary reservoirs. Game fishes comprise a lower percentage of the total population than in the storage reservoirs because environmental conditions favor the coarse species.

Among the 9 species of game fishes occurring in the lower reservoirs, largemouth bass, white bass and the sauger are the most important in the order named. Pan fishes are numerically more abundant than the game fishes, and although 11 species occur in the area, crappie and bluegills comprise almost the total catch. The most important food fishes are the catfishes, drum and the spoonbill sturgeon. A large number of coarse fish occur in the lower reservoirs, the most abundant being carp, buffalo, gizzard shad and gar. In the backwater areas these coarse fishes may make up 70 to 85 per cent of the weight of the total fish population.

The Tennessee River at its mouth is considered a clean stream. It is normally clear, has very low bacterial counts and B.O.D., and the plankton are those usually observed in clear waters having very little organic material.

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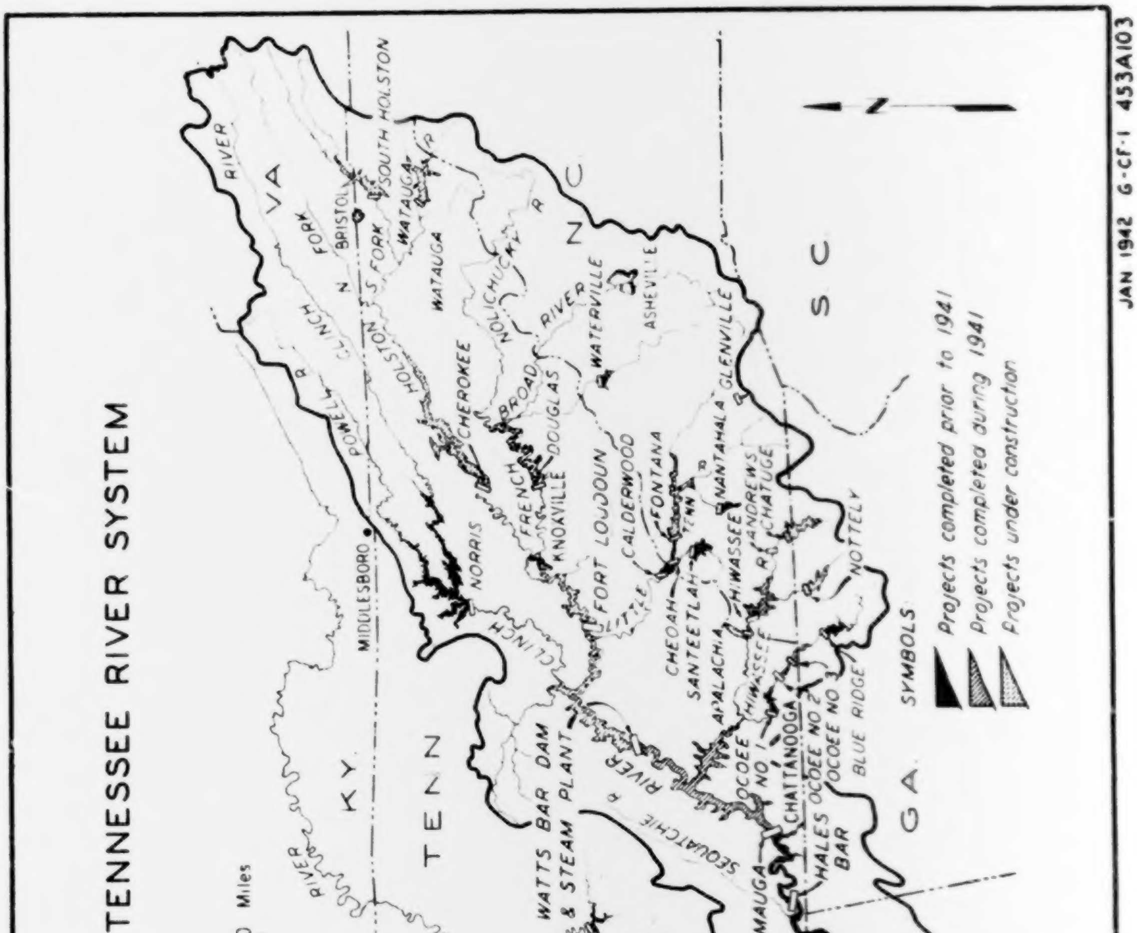
MAP OF THE TENNESSEE RIVER SYSTEM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IUKA
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